INTEGRATED EFFECTS OF INORGANIC FERTILIZER AND POULTRY MANURE ON THE GROWTH LEAF BIOMASS YIELD NUTRIENT UPTAKE AND PHARMACEUTICAL COMPOUNDS OF ALOEVERA GROWN IN SOME SOIL TYPES OF BANGLADESH

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CERTIFICATE

This is to certify that the thesis entitled " INTEGRATED EFFECTS OF INORGANIC FERTILIZER AND POULTRY MANURE ON THE GROWTH LEAF BIOMASS YIELD NUTRIENT UPTAKE AND PHARMACEUTICAL COMPOUNDS OF ALOEVERA GROWN IN SOME SOIL TYPES OF BANGLADESH" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY embodies the result of a piece of bonafide research work carried out by Tanzin Chowdhury, Registration No. 17-08181 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

I further certify that such help or sources of information, as have been availed during the course of this investigation have duly been acknowledged.

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INTEGRATED EFFECTS OF INORGANIC FERTILIZER AND POULTRY MANURE ON THE GROWTH LEAF BIOMASS YIELD NUTRIENT UPTAKE AND PHARMACEUTICAL COMPOUNDS OF ALOEVERA GROWN IN SOME SOIL TYPES OF BANGLADESH

ABSTRACT

Aloe vera had been used for numerous medical and cosmetic applications since ancient times. The gel of *A. vera* possesses healing ability of skin burns and cutaneous injuries, prophylactic effect against radiation leucopenia, antiulcer, anti-diabetic, anti-fungal, anti-bacterial, inflammation-inhibiting effect, anti-AIDS and anti-cancer. Unfortunately little attention was paid on different aspects of this herb in Bangladesh. Two separate experiments were conducted sequentially in the Department of Agricultural Chemistry, Bangladesh Agricultural University and Bangladesh Institute of Nuclear Agriculture, Mymensingh to find out the most suitable soil for *A. vera* cultivation, integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on the growth, leaf biomass yield, nutritional and pharmaceutical constituents of *A. vera* and post-harvest fertility of the soil. The economics of *A. vera* cultivation and public perception regarding the medicinal and commercial importance of this plant was also studied. Seedlings of 18 months old were collected from *Shomvogonj*, Mymensingh and planted during last week of May, 2017 for soil screening experiment, and 2nd week of October, 2017 for integrated experiment, respectively following CRD with three replications. Based on the findings of soil screening data, acid soil was used for the integrated experiment. Most of the soils were clay to clay loam in texture except non-calcareous and *charland* soil. The soils were acidic to neutral and organic matter content was low to moderate except peat soil. Different soil types significantly influenced the growth and leaf biomass yield of *A. vera*. Highest plant height, leaf number, leaf area and fresh weight were recorded from the plant grown in non-calcareous soil whereas maximum fresh gel weight, dry leaf weight and yield increase over acid sulphate soil were from the plant grown in calcareous soil. The performance of the soils in relation to leaf biomass yield was of the following order: calcareous ≥ acid ≥ non-calcareous > *charland* > saline 1 > saline 2 > peat > acid sulphate soils. Different combinations of IF and PM also exerted significant influence on the growth, leaf yield, nutritional and pharmaceutical contents of *A. vera*. The highest values of growth parameters and yield were obtained from the plant treated with 25% IF and 75% PM ($IF_{25}PM_{75}$) at harvest. About 153% yield increase over control was obtained from this treatment. The concentration and uptake of N, P, K and S were highest when the plants were treated with 100% IF whereas the highest uptake of Ca, Mg, Fe, Mn and Zn was noticed from 25% IF and 75% PM. Aloin concentration was increased with the increased application of PM. In contrast, highest chlorophyll, phenolic and flavonoid concentrations were found in the plants receiving the treatment $IF_{25}PM_{75}$. Fresh gel weight were significantly and positively correlated with plant height, number of leaves, leaf area and fresh leaf weight. Pharmaceutical compounds and mineral nutrients were also significantly and positively correlated with each other. Fresh gel weight and mineral contents like NPK were also strongly and positively correlated. The pH, organic matter, total N, exchangeable K, Ca, Mg and available P, S, Zn, B contents of post-harvest soil were significantly increased with the increased levels of PM. Based on BCR value (1.72), $IF_{25}PM_{75}$ was the best profitable treatment. People's perception revealed that 61% respondents used *A. vera* for curing various ailments and 72% respondents opined that the cultivation of this crop could be two to three times more profitable than other crops. Considering the overall socio-economic conditions of the farmers, it might be advised to cultivate *A. vera* in acid/calcareous soils applying 75% PM (5 t ha^{-1}) along with 25% inorganic fertilizer (N, P, K and S @150, 80, 120 and 30 kg ha^{-1}, respectively) under the agro-climatic conditions of the study area.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

%	Percent
µg g^{-1}	Microgram per gram
µL	Micro litre
AEZ	Agro-ecological zone
Appx.	Appendix
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BGA	Blue green algae
BM	Bone meal
CD	Cow dung
cm	Centimeter
cmol kg^{-1}	Centimole per kilogram
CRD	Completely Randomized Design
CV	Coefficient of variance
DAP	Days after planting
DMRT	Duncan's Multiple Range Test
EC	Electrical conductivity
FAO	Food and Agriculture Organization
FYM	Farm yard manure
g	Gram
hrs	Hours
IF	Inorganic fertilizer
K	Potassium
kg ha^{-1}	Kilogram per hectare
L	Litre
LSD	Least significant difference
mg kg^{-1}	Milligram per kilogram
mg $plant^{-1}$	Milligram per plant
mL	Millilitre
mm	Millimeter

MoP	Muriate of potash
N	Nitrogen
nm	Nanometer
No.	Number
NS	Not significant
^oC	Degree Celsius
OM	Organic matter
P	Phosphorus
pH	Potential of hydrogen ion concentration
PM	Poultry manure
PMHCL	Professor Muhammed Hussain Central Laboratory
PSB	Phosphate solubilizing bacteria
RDF	Recommended dose of fertilizer
rpm	Revolutions per minute
S	Sulphur
SD	Standard deviation
SRDI	Soil Resource Development Institute
TSP	Triple super phosphate
UNDP	United Nations Development Program
USD	United States Dollar
VAM	Vesicular arbuscular mycorrhiza
VC	Vermicompost

CHAPTER 1

INTRODUCTION

"Four vegetables are indispensable for the well-being of man: wheat, grapes, olives and aloe. The first nourishes him, the second he refreshes the spirit, the third brings him harmony and the fourth cures him". - Christopher Columbus (1451-1506).

The use of chemical and synthetic drugs has increased in the last half-century. The side effects of several synthetic drugs and development of resistance to currently used drugs for infectious diseases have led to increased emphasis on the use of plant materials as a source of medicines for a wide variety of human ailments. Medicinal plants encompass a wide variety of plants which are used for the prevention or treatment of diseases. One of the most important, world-famous herbs is Aloe. *Aloe vera* L. is an important medicinal plant from Xanthorrhoeaceae family (Ray and Shashaank, 2013) with African origin. The exudates of *A. vera* had been used for numerous medical and cosmetic applications since ancient times. The gel of *A. vera* possesses various biological and physiological activities in cosmetology and medicine, healing ability of skin burns and cutaneous injuries, prophylactic effect against radiation leucopenia, antiulcer, anti-diabetic, anti-fungal, anti-bacterial, inflammation-inhibiting effect, inhibition of the prostaglandin synthesis by anthraquinone-type compounds and inhibition of the AIDS virus by acemannan and anti-cancer (Eshun and He, 2005; Reynolds, 2004; Hamman, 2008; Hernandenez *et al.*, 2002; Ramachandra and Srinivasa, 2008).

From the leaves of aloe plants three types of commercial products can be obtained: the dried exudate, excreted from the aloin cells present in the zone of the vascular bundle; the gel, a mucilaginous juice present in the center of the leaf (hydrenchyma); and the oil, extracted by organic solvents (Burger *et al*., 1994; Baudo, 1992). The first, commonly called aloe, is a natural drug well-known for its cathartic effect and also used as a bittering agent in alcoholic beverages. The gel is utilized as a skin-care product and as a smoothening and softening agent in the cosmetic and pharmaceutical industries and as a dietary supplement in several beverages. The oil is the fatty fraction of the leaf and is used only in the cosmetic industry as a carrier of pigment and soothing agent (Baudo, 1992). The whole pharmaceutical and cosmetic world of both national and international market is dominated by *A. vera* and aloe derived compounds. In Bangladesh, about 80% of the population depends on herbal treatment particularly the Ayurvedic and Unani systems due to the effectiveness of the treatment in most cases and their relative safety as well as their low cost. A market study on medicinal plants conducted by Dixie *et al.* (2003) revealed that 1000 tonnes of fresh *A. vera* is used only for self-consumption per year in Bangladesh.

The market opportunity of *A. vera* is estimated to be approximately 90,000 USD (Dixie *et al.*, 2003). *A. vera* is now grown throughout the world especially tropical, subtropical, arid and semi-arid regions in general. Social perspectives of *A. vera* gradually increased throughout the country. Despite of its enormous potentiality, for commercial aspect, it is primarily grown around Natore, Tangail and Bogra districts of Bangladesh and is confined in a small pocket of the country (Dixie *et al.*, 2003). In Bangladesh the street hawkers mainly use it for the preparation of Sherbet (Dixie *et al.,* 2003).

The commercial cultivation of *A. vera* in Bangladesh is very limited, due to information gap regarding the traditional cultivation procedure, different management aspects, pharmaceutical values and marketing. Till now no research work has been conducted on cultivation procedure, different management practices, constituents of *A. vera* and their biochemistry with respect to medicinal and cosmetic uses. So, the need of the present hour is to conduct research on different aspects of *A. vera* in the country. If all the above information can be explored and made available from the root level farmers to policy makers, the cultivation of this plant can be popularized throughout the country.

A few sporadic trials on the growth and leaf yield of *A. vera* have been conducted at pot conditions (Hasanuzzaman *et al.,* 2008). Unfortunately no detailed study has yet been published on the suitability of soil, organic and inorganic fertilizer requirement, pest management, chemical and/or biochemical constituents *etc.* for large scale cultivation of *A. vera* in Bangladesh.

Soils of different types affect crop production according to their capability as a nutrient supplier based on plant requirement. Building healthy soil is an ongoing process because plants can deplete the nutrients in the soil as they grow. Soil provides physical support to plant as well as supplies necessary water and nutrient elements for plant growth and development. Plant growth basically depends on physical, chemical and biological properties of soil. Suitable soil for *A. vera* cultivation in Bangladesh should be identified.

Incorporation of *A. vera* into agricultural production systems depends upon detailed information regarding the plant, its agronomic potential and nutritional requirement (Ramesh *et al*., 2007). Nitrogen (N) is a key nutrient in manipulating plant growth. All vital processes in plant are associated with protein, of which N is an essential constituent. Consequently, getting more crop production, N application is essential in the form of chemical fertilizer (Ali *et al*., 2000). Optimum requirement of N need to be screened out for achieving maximum biomass yield of *A. vera* in Bangladesh. Phosphorus (P) plays key roles in many plant processes such as energy metabolism, the synthesis of nucleic acids and membranes, photosynthesis, respiration, nitrogen fixation and enzyme regulation (Raghothama, 1999). Potassium (K) content in the plant tissue is crucial to the proper functioning of several important biochemical and physiological processes that directly determine crop productivity. Information regarding K requirement of *A. vera* is not clearly mentioned anywhere including Bangladesh. Sulphur (S) is a component of methionine, cysteine and cystine, those are the essential building blocks of proteins. It is also a component of key enzymes and vitamins in the plant and is necessary for the formation of chlorophyll. The level of S in the soil is one of the critical factors determining the growth and yield of the plants (Lakkineni and Abrol, 1994). The requirement of S for the growth and biomass yield of *A. vera* is also unknown in Bangladesh.

Organic manure like poultry manure can improve the soil physical, chemical and biological conditions along with an increase in the amount of deficient nutrients where deficiency in the soil was observed. Poultry manure (PM) has long been recognized as perhaps the most desirable animal manures because of its high nutrient content. Along with the chemical fertilizers organic manures can be mixed to the soil to control nutrient deficiency, increase organic matter content, water holding capacity of the soil to stimulate the activity of beneficial microorganisms that makes the plant food elements in the soil readily available to the plants.

In view of the above fact, cultivation of *A. vera* gradually coming into focus in Bangladesh agriculture due to its enormous prospect both at home and abroad. Hence, the prevailing situation underscores the need for research to study the ideal soil condition and fertilizer recommendation for the cultivation of *A. vera* plant in Bangladesh. It is now imperative to develop an appropriate technique of cultivation and quantify the pharmaceutical compounds along with the nutritional and cosmetic compounds, economics and public perception regarding the pharmaceutical and economic importance of *A. vera* to boost up its production in Bangladesh. Looking at that end, the present piece of research work was carried out to fulfill the following objectives-

1. To find out suitable soil type for *A. vera* cultivation by evaluating the growth and yield performance.
2. To investigate the integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on the leaf biomass yield, nutrient uptake and pharmaceutical compounds of *A. vera*.
3. To examine post-harvest soil fertility as influenced by integrated fertilizer management and study public perception as well as economics of *A. vera* cultivation.

CHAPTER 2

REVIEW OF LITERATURE

This chapter presents a comprehensive review of the works related to the present study. The review focuses mainly on the response of different crops including *A. vera* to different types of soils, integration of inorganic and poultry manure and their effect on nutritional and pharmaceutical contents etc. Though research works have been done in many countries on different aspects of *A. vera*, no published reports are available in Bangladesh. Therefore, an effort has been made to enumerate some of the relevant works done on the above aspects elsewhere of the world. Few findings pertinent to the research are reviewed here under the following headings and sub-headings.

2.1 History of *A. vera*

A. vera L. (syn. *Aloe barbadensis* Miller), a miraculous plant, has a long history as a multipurpose folk remedy. Its name is most likely derived from the Arabic word Alloeh, meaning "shining bitter substance". *A. vera* L. belongs to the family Xanthorrhoeaceae and sub-family Asphodeloideae (Ray and Shashaank, 2013), is the most familiar and popular medicinal plant among the other species of *Aloe* genus. Tropical Africa is the original habitat of *Aloe* species but now *A. vera farming* is gaining up momentum in warm climate areas of Asia, Europe and America on account of its growing importance and increasing market demand. There are two beneficial products extracted from aloe leaves, namely 'gel' and 'sap', both of which show potential bio-activity with reference to pharmacological applications (Ray *et al.,* 2013a; Ray *et al.,* 2013b). Colorless astringent 'aloe gel' (AG) composed of parenchyma tissues is one of the widely used natural products in the world having unique immune boosting potential. Many biological activities including anti-viral, anti-bacterial, laxative, protection against radiation, anti-oxidant, anti-inflammation, anti-cancer, anti-diabetic, anti-allergic and immune stimulation have been attributed to 'aloe gel' (Ray *et al.*, 2013a; Ray *et al.,* 2013b; Choi and Chung, 2003; Rodriguez *et al.,* 2010). The plant gel increases fruits storage time and maintains their quality (Martinez *et al.*, 2006).

2.2 Agronomy of *A. vera*

It is a perennial plant that has stiff, tapering, marginated and turgid green leaves. The leaves reach 30-60 cm long, erected, green in color, covered with rounded specks and crowded in a basal rosette. The main root is 4–10 cm long and 4–5 cm in diameter, the rhizosphere is concentrated at a depth of 15–20 cm. Flowers 2.5–3 cm long, yellow, grouped in clusters on a single erect stem about 1m long. Reproduction is primarily by asexual plantlets. *A. vera* leaf is fatty and smooth. It contains two separate juice materials, the yellow latex (exudates) referred as “Aloe juice” or “Aloe sap” and the transparent mucilaginous gel (Aloe gel).

The inner structure of *A. vera* leaves are composed of three layers. These are: 1) The inner clear gel that contains 99% water and the rest is made of glucomannans, amino acids, lipids, sterols and vitamins; 2) The middle layer of latex bitter yellow sap that contains anthraquinones and glycosides and 3) The outer thick layer “rind” that contain cuticles and chloroplasts which has protective function in synthesis of carbohydrates and proteins. *A. vera* is the most versatile and nutritional store house, nature favor to it by giving enormous nutrients and bioactive compounds. It is a nutrient tower that contains around 75 nutrients and 200 active compounds including minerals, amino acids, enzymes and vitamins. *A. vera* is found to grow in hot humid and high rainfall conditions. It grows well in bright sun light. Shady conditions results in disease infestation. A rainfall ranging from 1000 – 1200 mm is ideal for *A. vera* cultivation. Although McKeown (1987) describes aloe as a subtropical species that is intolerant of low temperatures, an experiment in the Golan heights (Israel) in 1995 showed that it can reach commercial size with an absolute minimum temperature of −3°C and up to 2 months with a temperature of ≤ 4°C (Saks and Ish-Shalom-Gordon, 1995). Irradiance significantly affects plant development (Pedroza-Sandoval and Gómez-Lorence, 2006). In the cultivation of young plants, Paez *et al*. (2000) in Chile showed a direct correlation between partial shade (30% full sunlight) and yield: with 27% more leaves than plants under full sunlight.

2.3 Soil condition

Aloe is grown in all kinds of soil with high organic matter content (Kent, 1980). Good drainage of the soil profile must be guaranteed to prevent puddling, which could cause root asphyxia and the spread of root apparatus diseases such as tracheo-micosis by both *Fusarium oxysporum* and *Verticillum* sp. (Ayodele and Ilondu, 2008). The channeling of drainage water must also prevent the formation of surface puddles during the rainy season. It grows well in bright sun light. Shady conditions results in disease infestation. Since it is difficult to grow *A. vera* from seeds, seedlings are normally raised from roots of the plants. Sucker itself can be used as seedlings as in Banana. Rainy season is ideal for sucker plantation. About 2-3 ploughings and laddering are done to make the soil weed free and friable. Land leveling is then followed. Along the slope, 15-20 ft apart drainage is made.

The plant grows best when supplied with an excess of 50 cm of rain annually, in N-rich, alkaline soil. Soil N should ideally be maintained at 0.40%–0.50% while most species of Aloe typically grow well in sandy soils. Aloe is grown in all kinds of soil with high organic matter content, saline soils of beach areas in tropical and subtropical xerophytic conditions. Several researchers (Kent, 1980; Rahi *et al.*, 2013; Jin *et al.*, 2007) studied the physiological response of *A. vera* to saline stress (EC: 23 dS m^{-1}) which causes a decrease in the water content in the plant tissues as well as in total soluble sugars and glucose. Rahimi-Dehgolan *et al*. (2012) irrigated plants with fresh (EC control: 0.4 dS m^{-1}) or saline lake water (EC: 3, 6, 9, 12, 15, 18, 21 dS m^{-1}): irrigation with saline lake water up to 9 dS m^{-1}, increased the concentration of glucose, xylose and mannose in the leaf gel.

Rodríguez-García *et al*. (2007) found that low soil water content reduced the fresh weight, number of leaves and growth rate of the plants. Murillo-Amador *et al.* (2007) evaluated the effect of one irrigation volume (20 mm per hrs), different times (1.5 and 3 hrs) and two intervals (once and twice per week) in the production of leaf biomass and gel in an arid zone of Mexico. Their results showed that the production of leaves and gel increased when 20 mm per hour were applied for 3 hrs, once per week. Nowadays, cultivators of *A. vera* for commercial purposes stress the fact that low temperatures are devastating to the plant (Kent, 1980; Mckeown, 1987). However, *A. vera* prospers in the Israeli deserts, characterized by low winter temperatures, including frost events. Since, in this respect, the hypothesis that *A. vera* could be cultivated in the Golan heights was tested in a study (Saks and Ish-Shalom-Gordon, 1995). Single well developed *A. vera* plants, found growing in private gardens in various regions of the heights, served as a preliminary observation strengthening this hypothesis.

According to the above-mentioned references the common habitats for *A. vera* are mainly dry coastal rocks, sandy plains and dunes (Kent, 1980).

2.4 Effects of inorganic fertilizers (IF) on growth and yield of different crops

Ingawale (1979) mentioned that application of 150 kg N, 120 kg P_2O_5 and 60 kg K_2O ha^{-1} to gaint double african orange marigold gave significant increase in spread of the plant, stem thickness, number of branches and leaf area index. Nalawadi (1982) reported that in marigold, highest plant height, number of leaves and yield were obtained with the application of 225 kg N and 120 kg P_2O_5 ha^{-1}. Venugopal (1991) noticed the increased values of plant height, number of branches, number of leaves, leaf area and dry matter production with increase in N levels up to 200 kg ha^{-1}.

Narayanagouda (1985) noticed increase in plant height, number of nodes, branches, leaves number, leaf area and dry weight at 180 Kg N, 120 kg P_2O_5 and 100 kg K_2O ha^{-1}. Mantur (1988) reported that higher plant height, number of branches, total dry matter accumulation, leaf area, leaf area index, leaf area duration with a combination of 180:120:75 kg NPK ha^{-1} in China aster. Mokashi (1988) stated that in Gaillardia, the increasing levels of N (120 to 180 kg ha^{-1}) and P (80 to 120 kg ha^{-1}) did not increase the plant height, number of branches, number of leaves and plant spread. Singhlodhi and Tiwari (1993) observed significant increase in plant height and spread in chrysanthemum with the application of 45 g N along with 45 g P m^{-2}. In golden rod, Ryagi and Nalawadi (1994) mentioned higher plant height, number of leaves, leaf area and total dry matter production due to increased levels of N. In an experiment from Korea, Lee *et al*. (1980) reported that stevia leaf yield increases with moderate application of N, P and K fertilizers.

Das *et al.* (2006) found the amounts of available phosphorus (P) and potassium (K) in soil have been found to be increased initially up to 45 days and thereafter decreased with the progress of stevia plant growth up 60 days irrespective of treatments. However, the magnitudes of such increases in N, P and K contents both in soils and stevia plants have also been enhanced with the simultaneous application on N, P and K (40: 20: 30 kg ha^{-1}) over that of their corresponding individual applications. The amount of available P and Zn content in soil increased initially and thereafter, the amount of the same decreased with the progress of plant growth up to 60 days irrespective of treatments. The amount of P and zinc (Zn) in soils showed an increase with their separate applications either as soil or foliar spray while that of the same value significantly decreased both in soils and plants due to their combined application suggesting a mutual antagonistic effect between Zn and P affecting each other's availability in soil and content in the stevia plant (Das, 2005). Ganga (1981) investigated that total dry matter production (g plant^{-1}) and its distribution into leaves, stem and fruiting parts of safflower at various growth stages was more with 120 kg N and 80 kg P_2O_5 ha^{-1}. Nalawadi (1982) observed a linear increase in dry matter production with the increase in N level from 75 to 225 kg ha^{-1} in marigold. With the increase in N application, he observed increased plant height, branching, plant spread, leaf area index and leaf area duration in marigold (*Tagetes erecta L.).* Application of N up to 40 g m^{-2} significantly increased the plant height and number of branches in marigold (Arora and Sing, 1980). Leaf area index has been considered as one of the physiological index in determining the crop yields as it represent the size of the photosynthetic system. So, the leaf area is indispensable observation to be made on manurial experiments. The leaf area varies from season to season. Petric *et al.* (1943) reported that in general, restriction of water supply reduced the leaf area. It was, however, true only in the earlier part of the growth period in the field crops. Waston (1952) reported that any treatment that influences the leaf area and dry matter would have a bearing on the final yield.

Brougham (1960) found a positive correlation between leaf area index absorbing 95 per cent of light and maximum growth rate of different species. Several workers reported that N increased the leaf area (Waston, 1952). Extensive trials by Penningsfield (1973) on the nutrient requirement of herbaceous plants revealed that phlox tolerated up to 300 kg N ha^{-1} and chrysanthemum grew best with 200 kg N ha^{-1}.

Sheelevantar (1973) also reported that higher fertilizer levels produced the highest leaf area over the control and treatment with low levels of nutrients. Thomas *et al*. (1976) from their studies of the leaf area index observed that net assimilation rate of sunflower variety, Peredovik as influenced by graded dose of N and P and also revealed that increased N application increased the leaf area.

Maheshwar (1977) reported increased leaf area with increased nutrient levels and attained maximum leaf area on 56th day after transplanting. Till 56th day, N at 180 kg ha^{-1} proved its superiority in maintaining higher leaf area index with both N and P was noticed with advancing stages of growth. Hegde and Havanagi (1987) reported that at high fertility level (80 kg N + 80 kg P_2O_5); LAI was significantly superior which in turn helped to realize higher yields in sunflower. Sharanabasappa (1990) reported that increased leaf area, leaf area index and total dry matter production with increasing levels of N from 0 to 150 kg ha^{-1} in Helichrysum.

2.5 Effects of poultry manure (PM) on growth and yield of different crops

Poultry manure (PM) improved tomato growth than that of goat dung, while cow dung (CD) was the least effective organic fertilizers (Siddiqui and Akhter, 2007). Farhad *et al.* (2009) conducted an experiment to study the effect of PM on maize. The experiment consisted of six treatment: 0, 4, 6, 8, 10 and 12 t ha^{-1} PM. Results showed that plant height, number of rows per cob, number of grains per row, 1000-grain weight, grain yield, biological yield and harvest index were significantly affected by the application of PM. Maximum values for all these parameters were recorded from PM @ 12 t ha^{-1}.

Detpiratmongkol *et al*. (2014) conducted a study to investigate the effect of chicken, pig and cow manure @ 2.5, 5, 7.5, 10, 12.5 t ha^{-1} on yield, leaf area index, stem, leaf and total dry weight of Kalomegh (*Andrographis paniculata*).

The results revealed that chicken manure gave the highest leaf area index, and dry matter yield followed by pig manure, while cow manure gave the lowest. In general the yield increased significantly with increased manure rates. The higher manure rate of 12.5 t ha^{-1} gave a significantly higher plant height, stem and leaf dry weight than 2.5, 5, 7.5 and 10 t ha^{-1}. There was no significant difference between the types of organic manures. However, application of 12.5 t ha^{-1} of chicken manure resulted in a significantly higher performance of growth parameters, total dry matter yield when compared to 2.5, 5, 7.5 and 10 t ha^{-1}, respectively.

Channabasavanna and Biradar (2001) reported that the application of PM @ 3 t ha^{-1} gave 26% and 19% higher grain yield than that of the control during 1998 and 1999, respectively. Eneji *et al.* (2001) observed that across the soils, the average level of extractable Fe increased by 5% in chicken manure and 71% in cattle manure; Zn by 312% in chicken manure and 871%

in swine manure; Mn by 61% in chicken manure and 172% in swine manure and Cu by 327% in chicken manure and 978% in swine manure. Although there was increased yield following application, the results of this study indicated a possible risk of trace element export to the environment within a year, if high levels of the manures are applied.

Gupta (1995) conducted field trials on different organic manures in India and reported that the application of pig manure (10 t ha^{-1}) produced the highest grain yield (4.5 t ha^{-1}) followed by PM and FYM which produced yield of 4.1 and 3.9 t ha^{-1} of rice grain, respectively. The increase in rice yield with organic manure was 34 to 55% higher over control and 5 to 22% higher over NPK fertilizer. Garg and Bahla, (2008) reported that PM is an excellent organic fertilizer, as it contains high N, P, K and other essential nutrients. PM supplies P more readily to plants than other organic manure sources. Miller, (2007) revealed that organic sources offer more balanced nutrition to the plants, especially micro nutrients which has caused better affectivity of tiller in plants grown with PM and vermicompost. Ibeawuchi *et al*. (2006) reported that in a degraded soil of Nigeria, PM application increased the residual soil N, K, Ca, Mg, and organic matter. The high organic matter with increase in other soil chemical components is an indication that PM has high potential of gradual nutrient release to the soil that can help to improve the fertility of a degraded soil thereby sustaining yield in a continuous cropping system. Akande *et al.* (2005) reported that complementary application of rock phosphates with PM increased maize grain yield by 33 and 26%, respectively while cowpea yield was increased by 25 and 32% in 2001 and 2002, respectively.

Nottidge *et al*. (2005) reported that the increase in soil organic C, N, P, K, Ca and Mg concentrations due to the application of organic amendments and NPK fertilizer is consistent with the analysis recorded for the PM and wood ash in the research work and the use of PM, wood ash and NPK fertilizer for improving soil fertility in crop production. The decrease in pH with amount of PM could be due to the humic acid developed and CO_2 evolved in the process of decomposition of PM. Sistani *et al*. (2004) revealed that poultry litter is used as a soil amendment to add nutrients and organic matter, thereby increasing soil fertility. Poultry litter is considered a relatively inexpensive source of macro and micronutrients and its application rates are usually determined in terms of the N, P, and/or K provided.

Mullins *et al*. (2002) reported that PM is used as a source of N, P and K but litter also contains Ca, Mg, S and some micronutrients. They also revealed that poultry litter contained a considerable amount of organic matter due to the manure and the bedding material. Litter can also have an impact on soil pH and liming due to varying amounts of calcium carbonate in poultry feed. Uddin *et al*. (2002) reported that if PM can be added @ 4 t ha^{-1} the use of NPK can be reduced and S, Zn and B fertilizers may not be needed. Saitoh *et al*. (2001) performed an experiment to evaluate the effect of organic fertilizers (CD and chicken manure) and pesticides on the growth and yield of rice and revealed that the yield of organic manure treated and pesticide free plots were 10% lower than that of chemical fertilizer and pesticide-treated plot due to a decrease in the number of panicle.

Channabasavanna and Biradar (2001) conducted an experiment with 4 sources of organic manure (FYM 7 t ha^{-1}, rice husk 5 t ha^{-1}, PM 2 t ha^{-1} and press mud 2 t ha^{-1}) with one control and 3 levels of zinc (0, 25 and 50 kg $ZnSO_4$ ha^{-1}). Application of PM with 25 kg $ZnSO_4$ ha^{-1} gave significantly higher yields over rest of the treatments. The residual effect was more prominent when rice husk was applied. They cited that organic manure increased panicle $hill^{-1}$ and seed $particle^{-1}$. Babu and Reddy (2000) conducted a field experiment to examine the effect of NPK fertilizer, FYM and PM on rice. They applied 100:50:50 kg NPK ha^{-1}, 10 t ha^{-1} FYM, 5 t FYM +50 kg N as top dressing ha^{-1} or 3 t PM ha^{-1} and observed that grain yield were the highest with 5 t FYM+50 kg N ha^{-1}. Hemalatha *et al*. (2000) studied the influence of organic manure: dhaincha, sunhemp and FYM on rice productivity, quality and soil fertility. They reported that all the sources of organic manures improved the rice yield quality and soil fertility.

2.6 Effects of integrated application of organic and inorganic fertilizers on growth and yield of different crops

It is known that organic sources are not able to substitute mineral fertilizers because for example, the definition by Dudal (2002) states fertilizers as any material containing at least 5% of one or more major nutrients. This definition excludes almost all organic sources from substituting fertilizers. This is why the sole application of organic sources can seldom furnish plant with required nutrients for sustainable crop production unless huge quantities adjusted to N or P recommendation are applied (Vanlauwe and Giller, 2006, Vanlauwe *et al*., 2010).

While the main role of mineral inputs is to supply nutrients or correct unfavorable soil pH conditions, organic resources contain C, which drives all microbial and faunally mediated soil processes and finally replenishes the soil organic matter (SOM) pool, which maintains the physical and physico-chemical components contributing to soil fertility such as cation exchange capacity (CEC) and soil structure (Vanlauwe and Giller, 2006). Fertilizers are able to increase both crop yields and additionally produce enough residues for soil fertility management issues, while organic sources are able to rehabilitate less responsive soils and make them responsive to fertilizers (Vanlauwe *et al*., 2010).

According to Vanlauwe *et al.* (2010), the ability of fertilizers to produce enough residues for sustainable soil fertility management on one hand, and the ability of organic sources to rehabilitate less responsive soils and make them responsive to fertilizers have been proved by experimental results from Nigeria and Zimbabwe, respectively. Nziguheba *et al.* (2004), Bationo *et al.* (2007), and Sanginga and Woomer (2009) had similar views. They also attributed the increment in fertilizer use efficiency to two main reasons: (1) common mineral fertilizers lack the micronutrients essential for crop growth while organic resources contain them. Organic resources are not able to meet crop major nutrients needs (N, P, and K) unless it is applied in huge quantities more than 10 t ha^{-1} of dry matter. Therefore, combining both sources enable reasonable supply of all needed nutrients for a balanced growth. (2) a combination of both sources results in improvement in soil fertility status, increased SOM content which improves nutrient retention, turnover and availability; enhanced P availability thank to organic resources, alleviation of soil acidity and aluminium toxicity, improvement of the soil structure leading to reduced erosion, enhanced water infiltration and storage, and improved crop root development. Blackshaw and Brandt (2009) recognized that the additional P supplied by this combination may result in additional benefits in terms of yield and quality as it plays key roles in cellular energy transfer, respiration, and photosynthesis. Additionally, it is an important structural component of nucleic acids, coenzymes, phosphoproteins, and phospholipids. It is also essential for BNF, a source of 23 additional N in legume–cereal cropping systems (Mapfumo, 2011; Jansa *et al*., 2011). This is very much beneficial to inherently low P fertility soils (Amézquita *et al.*, 2007).

Hasanuzzaman *et al*. (2010) conducted a field experiment at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during June to November, 2008 to observe the comparative performance of different organic manures with inorganic fertilizers on the growth rate, tillering and dry matter accumulation of rice. They found that plant height, number of tillers hill^{-1}, total dry weight of plants, crop growth rate and relative growth rate were highest with the treatment of PM (@ 4 t ha^{-1} + $N_{40}P_6K_{36}S_{10}$ *i.e.* 50% NPK). The dry matter production also showed a significant relationship with grain yield of rice.

A field experiment was carried out in red loamy soil to study the effect on growth and yield of stevia as influenced by integrated nutrient management practices. Organic manures like FYM, PM and distillery bio compost were applied along with the inorganic fertilizers. The result indicated that application of 75% recommended doses of inorganic fertilizer with 25% PM recorded significantly higher plant height, leaf area and fresh leaf weight followed by the treatment containing 100% recommended doses of inorganic fertilizers (Soumya *et al.*, 2014). Khanom *et al.* (2008) reported that both the organic and inorganic fertilizers influenced leaf yield, yield attributes, nutrient content and their uptake by stevia leaf. Yan *et al.* (2012) mentioned that effect of different mixed fertilizers on the growth and development of stevia in the open field. The results showed that the growth rate, plant height, stem thickness, leaf areas and dry matter weight using organic cultivation were less than that of using the chemical fertilizers in the early stage after transplanting. But 60 days after transplanting (DAT), there were no significant differences among the treatments in agronomic characters besides control treatment. However, there were significant differences in growth and development between organic cultivation and using the chemical fertilizers in 80 DAT.

Results obtained by Dixit and Gupta (2000) revealed that application of FYM at 10 t ha^{-1} and blue green algae (BGA) inoculation either alone or in combination, increased the economic yield of rice. The average increase in the grain yield due to BGA was 0.24t ha^{-1}(7.5%) while combined use of FYM and BGA showed the increase of 0.60 t ha^{-1} (19.2%). Addition of FYM and BGA showed positive change in organic carbon and N content of the soil. Average P and K content also showed increasing tendency due to the treatment. Highest economic yield of the crop was noted in the treatment combination of N and FYM + BGA. Dihiphale *et al.* (2000) stated that FYM at 8 t ha^{-1} + 75% of the recommended rate (N: P: K at 75: 50: 50 kg ha^{-1}) resulted in higher panicle length, crop yield, number of filled grains panical^{-1} and panicle weight.

Meelu and Singh (1991) showed that 4 t ha^{-1} PM along with 60 kg N ha^{-1} as urea produced grain yield of crop similar to that with 120 kg N ha^{-1} as urea alone. Boswell (1975) reported an approximately 30% higher yield of fescue (*Festuca arundinaceous* Schreb) under excessive application of sewage sludge (5.6 Mt ha^{-1} dry wt^{-1}) given three times over a 2 years period compared to the control, whereas the increase in the forage yield was approximately 150% with NPK fertilizers (@ 224, 94 and 202 kg ha^{-1}, respectively) compared to the control.

2.7 Effects of organic and inorganic fertilizers on post-harvest soil properties

The physical and chemical composition of PM is influenced by the bird type, number of birds per unit area, kind and amount of litter, time of use and management factors (Eno, 1962). The quality of PM is equally affected by climatic conditions during litter production, and storage after production. Overcash (1983) reported that average daily fresh manure produced by broilers and hens is 18 and 22 kg 1000 kg^{-1} live weight day^{-1}, respectively also affected by feed.

According to FAO (1984), fresh droppings of chicken contain about 70% moisture. Hileman (1967) reported that one ton broiler litter could supply 6.38 kg Ca, 18.48 kg Mg, 1.01 kg Mn, 4.4 kg Fe, 0.18 kg B, 0.55 kg Zn and 0.015 kg Mo. PM has been found to improve upon both the physical and chemical properties of the soil when applied appropriately. Hileman (1967) and Bonsu (1986), have reported that PM improves the physical condition of both light and heavy soils. Improved physical conditions enhance aeration, ease of seed bed preparation, seed germination, water holding capacity, soil microbial activity, water infiltration and structural stability of the soil. Bandel *et al.* (1972) reported that PM chemically helps to ameliorate and improve micro-nutrient deficiencies in most soils. In a study in the rain forest zones (Agboola *et al.*, 1975) revealed that moderate PM application slowed down humus decomposition by half compared to mineral fertilizer. PM helps to correct Zn and Fe deficiencies in the soils and supplements NPK fertilizers in crop production (Miller *et al.*, 1970). The release of ammonia from poultry litter when incorporated into the soil raised the pH of soil hence reducing soil acidity (Hileman, 1971). Agboola *et al.* (1975) also reported similar chemical properties; they observed that the content of exchangeable Ca and Mg was increased and uptake of P improved while reducing Fe, Al and Mn with the addition of PM to the soil.

Poultry litter incorporation also increased organic carbon and N to the depth of 15 and 30cm, respectively (Kingery *et al.*, 1993). Addition of excess broiler manure to the soil according to Hileman (1971), however increased soil toxicity and renders it inefficient. Deeper incorporation may be desired for light porous soils than heavy or wet soils. Muller-Samann and Kotschi (1994) suggested working the manure close to the surface rather than burying it deep. Owing to its caustic effect and heat generation, application of PM shortly before cropping causes injury to crops (Bandel *et al.*, 1972). Incorporation with tillage also reduces N and P losses by volatilization and surface run-off.

An incubation period of one month after application before planting allowed total nitrification to avoid the risk of ammonia toxicity (Siegel *et al.*, 1975). Rate of magnification and nitrification, varies depending on climate and soil. In contrast, Hileman (1971) opined that there is no need for any incubation period before planting crops because of the rapid chemical changes in the soil following broiler litter incorporation. Yansen *et al*. (2005) studied the effect of organic manure and chemical fertilizers on pummelo. They reported that application of manure and inorganic fertilizer increased the soil nutrient content, strengthened the activity of soil enzymes, and the effect of organic fertilizer application was better than that of inorganic fertilizer. Correlation analysis indicated that there was extremely significant positive correlation between the activities of soil enzymes and the content of soil organic matter. Mehdi *et al.* (2007) conducted a field experiments to develop an economically viable integrated nutrient management practice on Khasi mandarins. Results showed that higher yield with highest economic return were observed where half of the recommended rate of inorganic N and P_2O_5were supplemented through Azotobacter and PSB along with K_2O and MOC at 7.5 kg plant^{-1}.

Available nutrient balance over the initial content showed maximum mining of N, while a positive balance was noticed in the case of P_2O_5 (initial year) and K_2O throughout the years of experimentation. Significantly highest soil organic carbon, and available N were observed where half of the recommended rate of inorganic N and P_2O_5 were supplemented through Azotobacter and PSB along with K_2O and MOC at 7.5 kg plant^{-1}.

Sorrenti *et al*. (2008) conducted a study to evaluate the effect of different organic fertilizer application strategies, as N source, on the vegetative growth of young *Citrus reticulata* cv. Clemenules plants grafted on *Poncirus trifoliata* and on the chemical and microbiological soil properties. The treatments consisted of control (unfertilized); mineral fertilizer (MF); vermicompost (VC); vermicompost + blood meal (VC + BM); and citrus compost (CC). They reported that plant growth was positively affected by VC + BM fertilizer application strategy compared to the other treatments. The supply of BM contributed to avoid the temporary soil N deficiency that occurred when organic fertilizer was incorporated into the soil. VC and CC strategies induced limited effects on plant growth likely due to the lower soil N availability than the plant requirements. Moreover, only VC + SB promoted soil total N and microbial soil respiration.

Khan *et al.* (2009) conducted a field experiment on three old acid lime plants to study the effect of nutrient management of organic manures, inorganic fertilizers and biofertilizer on fresh leaf contents and leaf chlorosis of acid lime in calcareous soils. Application of organic manures - FYM and press mud, biofertilizer (VAM) and inorganic agricultural grade iron pyrites either alone or in combinations significantly influenced the active iron and sap pH. Application of FYM either alone @ 50 kg per plant or in combination i.e. FYM @ 25 kg + Press mud 2 kg + Iron pyrites 200 g per plant were superior to other treatments in both the years. Marathe *et al*. (2009) conducted a field experiment to study the effect of integrated supply of organic manures, inorganic fertilizers and biofertilizers on soil properties and yield of sweet orange (*Citrus sinensis*) grown on Vertisol. They found that all organic manurial treatments were highly effective to improve the physical properties of soil, FYM to meet 100% N being the best. Application of wheat straw along with inorganic fertilizer was equally effective, especially for infiltration characteristics of soil.

Combined application of various organic manures to meet 50% N along with 50% of NPK and biofertilizers recorded significant increase in available N, P and K content in the soil with maximum fruit yields. Considerable increase of available Zn and Mn was observed with farmyard manure application and of Fe with vermicompost application alone or in combinations with inorganic fertilizers. Seran *et al*. (2010) reported that the inorganic fertilizers appear to have compensated with slow release of nutrients from the compost and their combined effects would have increased the yield. From this study, it could be stated that half fold of the inorganic fertilizer and compost at the rate of 4 t ha^{-1} could give profitable yield and this combination could possibly reduce the cost of production in the cultivation of onion.

Santos *et al*. (2011) reported that there was an increase in the CEC, OM, N-total, P and K values in the soil managed with organic residues in *Ponkan madarin*. The sewage sludge application did not harm the soil quality because the input of elements As, Cd, Cr and Hg present in its constitution were not significant. In a field study conducted in the Middleveld agro-ecological zone at the Malkerns Research Station in Swaziland, the results showed that temperature at the soil surface was significantly higher than at lower depths and was negatively but not significantly correlated to some parameters: leaf area, leaf area index, specific leaf area, net assimilation rate and crop growth. Sweet potato yields declined with increased levels of chicken manure: 20 t ha^{-1} chicken manure yielded (20.6 t ha^{-1}); 40 t ha^{-1} chicken manure yielded (19.3 t ha^{-1}); and 60 t ha^{-1} chicken manure yielded (13.3 t ha^{-1}) (Magagula *et al*., 2010).

Guri (1986) stated that animal manure that is not well decomposed generates much heat in the soil. This heat can cause some soil microbes to become inactive and may also kill some young plants growing in the soil. It is therefore advisable after applying the manure on the land to leave it for at least two weeks to decompose well before planting. According to Leonard (1982), manure that is applied too far in advance may lose N by leaching. Fresh manure unlike decomposed manure should be applied a week or more in advance and should be ploughed in as early as possible.

2.8 Nutritional contents and pharmaceutical compounds of *A. vera*

Aloe (*A. vera* L.) is one of the most economically important medicinal crops worldwide with a significant bio-cultural value (Grace *et al.,* 2009; Grace, 2011) and has a long history. Traditionally used for healing in natural medicine, for the last 20 years aloe has been at the center of a renewed interest in the global market due to its therapeutic and nutritive substances extracted from leaves, used in commercial preparations for pharmaceutical, cosmetic or alimentary uses and as a fresh food (Gutterman and Chauser-Volfson, 2007).

The leaf mesophyll, commonly known as aloe gel, is subject to industrial processing to obtain derivatives. The three structural components of the *A. vera* pulp are the cell walls, the degenerated organelles and the viscous liquid contained within the cells. These three components of the inner leaf pulp have been shown to be distinctive from each other both in terms of morphology and sugar composition (Ni *et al.,* 2004). The raw pulp of *A. vera* contains approximately 98.5% water, while the mucilage or gel consists of about 99.5% water (Eshun and He, 2005). The remaining 0.5 – 1% solid material consists of a range of compounds including water-soluble and fat-soluble vitamins, minerals, enzymes, polysaccharides, phenolic compounds and organic acids (Boudreau and Beland, 2006).

Aloe gel has polysaccharides (55%), sugars (17%), minerals (16%), proteins (7%), lipids (4%) and phenolic compounds (1%) on dry matter basis (Luta and McAnalley, 2005). The *A. vera* gel has many vitamins including the important vitamins A, C and E. Vitamin B1 (thiamine), niacin, Vitamin B2 (riboflavin), choline and folic acid. The most important are the long chain polysaccharides, comprising mannose and glucose, known as the glucomannans [β (1, 4)-linked acetylated mannan]. Calcium, Mg, Zn, Cu, Cr and Fe were found in the aloe products. It has been hypothesized that this heterogeneous composition of the *A. vera* pulp may contribute to the diverse pharmacological and therapeutic activities which have been observed for aloe gel products (Talmadg *et al.*, 2004). Haque *et al.* (2014) reported that the leaves contained fat 1.83%; protein 10.50%; ash 19.50%; carbohydrate 56.27%; P 1.90 mg g^{-1} and energy 290.08 kcal.

More than 75 active ingredients from inner gel have been identified including vitamins, minerals, enzymes, sugars, anthraquinones or phenolic compounds, lignin, saponins, sterols, amino acids, and salicylic acid. Among its most representative organic biomolecules, aloe gel contains soluble sugars, anthraquinones, β-polysaccharides, amino acids, vitamins, glycoproteins, and enzymes (Ahlawat and Khatkar, 2011; Lucini *et al.*, 2015), with various biological properties such as antiviral, antibacterial, antifungal, anticancer, anti-inflammatory, wound healing, and many other characteristics that have prompted an increase in industrial and commercial production globally (Boudreau and Beland, 2006). Different mechanisms have been proposed for the wound-healing effects of Aloe gel, which include keeping the wound moist, increasing epithelial cell migration, more rapid maturation of collagen, and reduction in inflammation (Reynolds and Dweck, 1999). A 1996 study reported that a high molecular weight polypeptide constituent from the gel demonstrated a healing effect on excisional wounds in rats (Davis, 1993). Glucomannan, a mannose-rich polysaccharide, and gibberellin, a growth hormone, interact with growth factor receptor on the fibroblast, thereby stimulating its activity and proliferation, which in turn increases collagen synthesis after topical and oral application (Heggers *et al.*, 1996).

Aloin and its gel are used as skin tonic against pimples. *A. vera* is also used for soothing the skin, and keeping the skin moist to help avoid flaky scalp and skin in harsh and dry weather. The Aloe sugars are also used in moisturizing preparations (Barcroft and Myskja, 2003). Mixed with selected essential oils, it makes an excellent skin smoothening moisturizer, sun block lotion plus a whole range of beauty products. Due to its soothing and cooling qualities, Maharishi Ayurveda recommends *A. vera* for a number of skin problems (Joseph and Raj, 2010). Femenia *et al.* (1999) stated that 0.05 and 0.09% level of lipids and proteins, respectively in *A. vera* gel of four years old plant. Ahlawat *et al.* (2013) reported that the crude fat and crude protein of *A. vera* ranged from 0.03 to 0.06% and 0.06 to 0.08%, respectively and crude fibre content of gel ranged from 0.10 to 0.14 %. Total sugar and carbohydrate content of gel increased from 0.16 to 0.27 and 0.17 to 0.31%, respectively for 1 to 4 years of plant maturity.

2.9 Effects of organic and inorganic fertilizers on *A. vera* cultivation

Fertility in agronomic management is one strategy to boost the aloe yield, however to reduce production costs aloe fields are often not fertilized. Today, considering the importance of environmental issues, increasing attention is being paid to different fertilizers and the methods of application of these organic and inorganic fertilizers.

In Bangladesh, Hasanuzzaman *et al*. (2008) observed that aloe increased its number of leaves (+38%) and total leaf weight (+153%), with the application of 50% cowdung +50% soil, compared to the control (100% soil). García (2000) used one dose (4.6 t ha^{-1}) of bio compost and showed no clear effect on aloe growth. In Mexico, Murillo-Amador *et al*. (2007) showed that compost-based manure is effective and found that as the compost doses increased from 30 to 60 t ha^{-1}, the leaves and gel yield increased.

Nitrogen fertilizer may enhance both growth and yields because the N supply helps in the full expansion of the leaf, chlorophyll content, photosynthetic rates and subsequently increases the supply of carbohydrates to the plants (Khandelwal *et al*., 2009). The application of 150 kg N ha^{-1} resulted in an increased both number and size of leaves, and total yield (Bharadwaj, 2011). Pedroza-Sandoval and Gómez-Lorence (2006) also reported the use of urea as an N source with one dose of 500 kg ha^{-1} and two applications per year. The simultaneous application of N fertilizer in the 17th week after planting, increases the number of leaves (Hazrati *et al.,* 2012). The foliar application of amino acid had positive effects on the content of secondary metabolites, antioxidants, and antioxidant activity (Ardebili *et al.,* 2012). In many species, mycorrhizal symbiosis improves the transfer of nutritive elements to the roots, ensures greater plant growth, and stimulates the formation of a more dynamic root apparatus, making it more extensive and branched. In the literature, there are contrasting results regarding mycorrhizal applications in aloe (Tawaraya *et al.*, 2007; Cardarelli *et al.,* 2013; Sharma *et al.,* 2013).

Rea *et al.* (2008) evaluated the effect of the replacement (partially or totally) of peat, with increasing doses of green compost, derived from ornamental tree pruning. In the first half of cultivation, the replacement equaled the performances of both the plant height and diameter, and improved both leaf numbers and plant fresh weight. In the second half, there were no significant differences between the substrates; plants did not show any phytotoxicity, and appeared disease free and with no weeds. Saha *et al.* (2005) reported that organic source of fertilizer in the form of vermicompost and vermiwash was found to be effective and comparable with inorganic source of fertilizer for increasing content of gel moisture, gel ash and aloin of *A. vera***.** Rajendran and Gnanavel (2008) found that the highest leaf yield of *A. vera* (56.24 t ha^{-1}) was significant recorded at application of neem cake @ 1.501 t ha^{-1} as compared to other application of manures.

Hoseini *et al.* (2013) reported that the highest numbers of leaf and fresh weight, leaf diameter and chlorophyll index of *A. vera* were achieved when pigeon manure was applied as compared to palm and vermicompost. Guleria *et al.* (2013) reported that plant grown in vermicompost and FYM pretreated soil exhibited maximum increase in all morphological parameters such as root length, shoot length, and number of root branches and number of stem branches of *A. vera*. Mishra and Ram (2014) observed that plant produced highest number of leaves, maximum leaf weight and maximum leaf breadth of *A. vera* with application of 50% CD + 50% soil. Different plant characters such as weight of tillers stem and root as well as root length of *A. vera* was also found to be highest with 50% CD + 50% soil as compared to the control (100% soil).

2.10 Effects of organic and inorganic fertilizers on nutritional contents and pharmaceutical compounds of crops

The application of animal and farm waste with or without chemical fertilizers improved not only soil fertility but also enhanced yield and quality of produce. Mofunanya *et al*. (2015) evaluated the effect of organic and inorganic fertilizer on phytochemical values of *Amaranthus spinosus*. Phytochemicals (percentage of crude alkaloids, tannins, saponins, flavonoids and reducing compounds) were higher in organic leaf samples compared to inorganic fertilizer. Organic fertilizer resulted in significantly ($p<0.05$) higher crude protein, fibre, ash and fat in leaf sample compared to inorganic fertilizer. Islam and Nahar (2012) stated that the nutrient content of P, K, Ca, Mg, Zn of tuber and haulm, and starch and protein content in tuber were highest in cowdung treated potato and N and S content of both tuber and haulm were highest in case of PM over conventional inorganic fertilizers treated potato. Srikumar and Ockerman (1990) also reported that crude protein content of potatoes influenced by organic manures (7.49 – 8.16 %) over inorganic fertilizer.

In a pot experiment conducted at the net house of Bangladesh Agricultural University, the result revealed that protein and oil content of mustard increased significantly due to application of cage system PM @ 20 t ha^{-1} (Zamil *et al*., 2004). The highest increase of protein content in seed over control was also found in CS-PM@ 20 t ha^{-1} and lowest increase was found in BS @10 t ha^{-1}. Dixit and Gupta (2000) reported that farm yard manure or biofertilizer either alone or in combination showed an increasing tendency of protein content in rice grain. Milkha *et al.* (1998) conducted field experiment for four years to evaluate the effects of different rates of fertilizer N and S with or without cowpea green manuring on yield, nutrient uptake, protein and oil content of mustard. The residual effects of green manuring were assessed on the succeeding rice crop.

Biochemical parameters of tomato cultivated with different treatments showed recommended quantity of N in the form of PM recorded highest contents of reducing sugar, non-reducing sugar, quantitative crude protein and ascorbic acid content. It might be likely due to the maximum production of these biochemical parameters in the occurrence of most favorable uptake of essential nutrients needed by tomato. In N rate trials with spinach, increasing rates of N showed an inverse relationship with ascorbic acid accumulation in potatoes, tomatoes, and citrus fruits (Mozafar, 1993). Excess N fertilization rates may decrease levels of vitamins, secondary metabolites, and plant quality (Stefanelli, 2010; Mozafar, 1993 and Li *et al*., 2010). Studies with basil confirmed the significant effect of N fertilization on TPC (Nguyen and Niemayer 2008). Phenolic activity increased when N was a limiting factor. Plants provided with the highest N rate had the lowest TPC levels.

A ten year comparison of organically and conventionally grown tomatoes conducted by Mitchell *et al*. (2007) found that increased flavonoid content in organically grown tomatoes attributed to the limitation of available N to the plant. In their words, "The differences detected appear to be correlated with differences in soil fertility management associated with conventional and organic farming systems," as soil organic matter reached a maximum in the organic systems, and the amounts of composted manure applied to these plots were subsequently reduced. They suggested that the lower total N accumulation in the most recent six years was the driving factor for increases in secondary metabolites, including flavonoids. Organically grown vegetables had much higher antioxidant and antimutagenic activity when compared to the same conventionally grown crops from a nearby farm (Zhao, 2006). This further supports Brandt's and Mølgaard's affirmation that "on average, organic vegetables and fruits most likely contain more of these compounds than conventional ones, allowing for the possibility that organic plant foods" that humans eat "may in fact benefit human health more than corresponding conventional ones" (2001). It is important to note the strong suggestion that the organic fertilizers themselves are not the reason for increased secondary metabolites in plant foods, but rather this occurs due to the effects of decreased access to quickly mineralized N.

Toor *et al.* (2006) grew tomatoes using chicken manure, grass-clover mulch, and two different nitrates: ammonium ratio fertilizers under weekly fertility treatments of 650 mg N week^{-1}. The manure and mulch treatments provided N in applied quantities that were equivalent to that of the mineral fertilizers. The mean TPC of the tomatoes grown in chicken manure and grass-clover mulch were 17.6% higher than those grown under either mineral nutrient solution. Further, the mean antioxidant activity of tomatoes grown under the mineral nutrient solution with the highest level of ammonium was 14% lower than the other treatments. As reported by Toor *et al.* (2006), the nutrient source had a significant role in the determination of antioxidant levels in tomato. Chopra *et al.* (2017) suggested that sole vermicompost and 50% IF along with vermicompost @ 5 t ha^{-1} could be used to achieve the maximum crop yield of tomato. They reported that among different treatments of organic manures and inorganic fertilizers the highest plant height, root length, dry weight, chlorophyll content, LAI, number of flowers plant^{-1}, fruits plant^{-1}, crop yield plant^{-1} and biochemical ingredients like crude protein, dietary fiber, total carbohydrates and total sugar of tomato was recorded with 50% inorganic fertilizer and vermicompost @ 5 t ha^{-1}.

Chlorophyll content is the important index to photosynthetic activity of crops, and there was a very close relationship with growth and yield. Chlorophyll content was approximately proportional to leaf N content (Evans, 1983) and N content in the leaf was in relation with colour of leaf (Carbrera, 2004). Because a close link between chlorophyll and N content exist, therefore chlorophyll content in plants leaves could be determined by new non destructive method by level supplied of plants with N (Monje and Bugbee, 1992). Madhav (2011) reported that a combined application of vermi manure and chemical fertilizers up regulated maximum chlorophyll a (5.5-fold), b (2.3-fold), total chlorophyll (4.6-fold), chlorophyll a/b ratio (2.3-fold) and soil dehydrogenase enzymes activity (2.0-fold) as compared to unfertilized plants. Stimulative effect of organic and inorganic fertilizers was also reported on chlorophyll content in apricot by Stino (2009). PM treatment as fertilizer resulted significantly higher chlorophyll content than those with N.P.K. and no treatment application (Amedor, 2014). Presence of N in soil and chlorophyll in plants are directly related. He further stated that chlorophyll could be used as an indirect indicator of N levels in fertilizer management. Based on this claim, it is possible that the PM released more N to the lettuce than NPK.

Construction and function of effective substances of medicinal plants are influenced by environmental factors such as deficiency or increased nutrients in the soil and substrates (Yavari *et al.*, 2013). The effects of vermicompost were examined on phytochemical features in *A. vera* by Yavari *et al.* (2013). They showed that the maximum leaf weight, gel weight, dry weight of gel and gel glucomannan was obtained in 45% of vermicompost. The maximum gel phenol, antioxidant activity of gel and anthocyanins of cortex belonged to 30% of vermicompost and gel flavonoid in 15% of vermicompost. The investigations of Ghasemzadeh and Jaafar (2011) in *Zingiber officinale* confirmed that the increase in photosynthesis, high flavonol content and phenolic compound was associated with high antioxidant activity. According to Atiyah and his colleagues (2002) the enzyme that was produced by microorganisms in vermicompost had an effect on the physiological activity and antioxidant capacity. The study of Nur and others (2012) also revealed the highest antioxidant capacity of cassava in the organic fertilizer vermicompost. The research of Alizadeh and others (2010) showed that the antioxidant activity was increased in all treatments, but there were no significant differences between treatments on the *Satureja hotensis*. It was also shown that there was a positive correlation between total phenolics and antioxidant activity in this plant. The results indicated that antioxidant activity was due to phenolic compounds in *Satureja hortensis*.

Increasing nutrient elements in the soil treated with vermicompost led to more secondary metabolites synthesis. The increase in phenolic concentration related to the balance between carbohydrate sources and sinks. Thus, when there are more carbohydrates, there are also more phenolic compounds (Lattinzo *et al.*, 2009 and Mathew and Abraham 2006). However, excessive use of vermicompost increases a substrate’s salinity which has inhibitory effect on plant’s activity. This can reduce the photosynthetic rate and reduce the amount of phenolic compounds in high percentages of vermicompost.

In another investigation done on the various ecotypes of *A. Vera*, it was determined that the nutrients have a positive influence on the rate of the active substance, Aloenin. As the gel weight increases, the rate of active substance was enhanced (Alagukannan *et al.*, 2008). Examining *A. vera* indicated that plants being able to use the most of nutritive and optical sources had a better growth and the plants with shadowing produce more leaves and splits

(Kawther *et al.,* 2002). In another investigation on the medicinal plant, namely *A. vera,* it was observed that the nutrients such as N increased the plant growth and rate of active substance (Alejandra *et al.,* 2000). In other words, the plants which received more levels of vermicompost produced active substances more than those receiving lower levels of vermicompost because of lower growth of vegetative organs. A study done on the vegetative growth and Aloenin rate in a variety of ecotypes showed that the increase in active substance rate depends on the environmental conditions such as nutrients. The aloin content derived from aloe was found to be higher in organic based fertilizers than inorganic ones (Saha *et al*., 2005). They revealed that maximum aloin content of 19.62% was in FYM followed by 17.81% in vermicompost + vermiwash. In case of chemical fertilizer the aloin content was increased at fertilizer level $N_{80}P_{40}K_{80}$ or more as compared to control.

2.11 Economics of crop cultivation

Rasheed *et al.* (2004) found that the economic benefits, significantly greater net income (Rs. 48137.0 ha^{-1}) and cost benefit ratio (BCR) (3.90) was obtained from the hybrid maize planted on ridges than that grown either in 105 cm spaced double row strips (Rs.45491.5 ha^{-1}) and BCR (3.85) or in 70 cm spaced single rows (Rs. 38299.5 ha^{-1} and BCR 3.40). Tiwari (2006) reported that vermicompost and FYM at 10 and 20 t ha^{-1} resulted in net returns (Rs. 3,30,800, 3,60,000 and 3,58,100 ha^{-1}), and BCR (2.18, 2.33 and 2.27) of safed musli than the control. Kumawat *et al.* (2006) recorded that application of vermicompost @ 4.5 t ha^{-1} recorded significantly higher net return of barley over rest of the combinations of organic manure. Barik *et al.* (2006) noticed that the highest gross return in wet season rice production was obtained under 50% recommended NPK + 10 t vermicompost ha^{-1} which was significantly higher than the treatment with 75% recommended fertilizer dose along with FYM.

Roul *et al*. (2006) reported that reduction in the recommended dose of N blended with organic manures failed to sustain the productivity of rice. Urkurkar *et al.* (2006) found highest yield sustainability and net return of rice and available N in soil under 50% of N substituted through green manure in conjunction with 50% of recommended NPK through inorganic fertilizers than 100% RDF and other combination of organic and inorganic sources. Deshpande and Devasenapathy (2010) obtained higher net return of rice with incorporation of green manure + PM (Rs. 45,272 ha^{-1}) along with higher BCR (3.37). The cost of cultivation also reduced comparatively than the vermicompost because of its higher cost as compared with PM. Gopinath and Mina (2011) reported that the application of FYM 10 t ha^{-1} + recommended NPK gave highest net returns (Rs. 63,295 ha^{-1}) of garden pea compared to other treatments. However, all organic treatments except vermicompost 7.5 t ha^{-1} + biofertilizer gave net returns (Rs. 64,148-75,489 ha^{-1}) than application of FYM 10 t ha^{-1} + recommended NPK, when a price premium (10-15%) was assigned to organic garden pea.

Ram *et al.* (2011) reported that the highest net returns and BCR recorded in raised bed were significantly higher than flat bed and ridge furrow methods of planting. Khan *et al.* (2012) reported that the maize sown on ridges exhibited higher while sown on flat surface exhibited lower net income and BCR. Kumar and Singh (2014) recorded maximum net returns (Rs. 78,899.00 ha^{-1}) and BCR (3.90) of rajmash were realized under raised bed method of sowing followed by flat bed method. Kulmi and Tyagi (2010) reported that higher net return (100%) and incremental benefit cost ratio (IBCR) (11.4%) of safed musli (*Chloropyhtum borivilianum* Santapau & Fernandes) was obtained from application of PM @ 5 t ha^{-1} combined either with the soil application of *Azotobacter* or vesicular arbuscular mycorrhizae or *Trichoderma viride* @ 10 kg ha^{-1} than application of farmyard manure @ 40 t ha^{-1}. Gaikwad *et al.* (2011) recorded that maximum net realization and BCR (Rs.1093418, 1:5.5, respectively) of safed musli under treatment vermicompost @ 2 t ha^{-1} + *Azotobactor* as compared to other treatment combination.

The review of literature presented above thus gives an idea about different aspects of *A. vera* along with other crops. Agronomy, soil condition, effects of inorganic fertilizers and poultry manure on the growth and yield of *A. vera*, post harvest soil fertility, nutritional contents, pharmaceutical compounds, economics and public perception are very important for commercial cultivation of *A. vera* in Bangladesh. Therefore, the present investigation seems appropriate which will provide some valuable information to boost up *A. vera* production under the agro-climatic condition of BAU, Mymensingh, Bangladesh.

CHAPTER 3

MATERIALS AND METHODS

This chapter gives a brief description of soil, treatments, test crop, experimental design, cultural operations, data collection, analysis of plant and soil samples, weather and climate of the experimental location and analytical methods. The experiments were carried out sequentially with *A. vera* in the green house of Bangladesh Institute of Nuclear Agriculture (BINA) and the net house of the department of Agricultural Chemistry, BAU, Mymensingh during 2017-18. Different chemical analyses of soil and leaf samples were done in the laboratories of the departments of Agricultural Chemistry, Biochemistry and Molecular Biology, Professor Muhammed Hussain central laboratory (PMHCL), BAU, Mymensingh and SRDI regional laboratory, Dhaka from 2017 to 2018.

3.1 Geographical location

Geographically the experimental site was located at 24°75'N Latitude and 90°50' E Longitude at an elevation of 18 m above the sea level. The site belongs to the Non-calcareous Dark Grey Floodplain soil under the Agro-Ecological Zone of Old Brahmaputra Floodplain (AEZ-9) (FAO and UNDP, 1988).

3.2 Weather and climatic condition

The climate of the experimental area is under the sub-tropical climatic zone, which is characterized by moderate to high temperature, heavy rainfall, high humidity and relatively long day during *kharif* (April to September) and scanty rainfall, low humidity, low temperature and short day period during *rabi* season (October to March). The prevailing meteorological information during the plant growing period regarding mean temperature (^{o}C), total rainfall (mm), mean relative humidity (%) and total sunshine (hrs.) have been presented in Appendix-7.

3.3 Collection and preparation of soil samples

Seven types of soils namely acid, calcareous, non-calcareous, *charland*, saline, peat and acid sulphate were collected from different locations of seven districts of Bangladesh *viz. Fulbaria* (Mymensingh), *Sadar* (Natore), Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, *Melandoh* (Jamalpur), *Botiaghata* (Khulna), *Kotalipara* (Gopalganj) and *Pekua* (Cox's Bazar), respectively during the month of February-April, 2017.

Approximately 40 kg soils from each location were collected from 0-15cm depth of selected fallow land for soil screening experiment. In case of the other experiment, approximately 70 kg acid soil from *Fulbaria* (Mymensingh) was collected. The samples were separately put in to plastic bags and carried to the laboratory with proper tagging. The collected soil samples were made free from plant residues and other extraneous materials; then air dried, ground and sieved through a 2mm sieve. The whole process was done several times until adequate amount of soil was prepared for the experiment. Approximately 500 g sieved soil from each source was preserved in a polythene bag for physical and chemical analyses.

3.4 Pot preparation

The soil was mixed thoroughly with poultry manure and inorganic fertilizers as per treatments. In soil screening experiment, well decomposed dry cow dung (CD), urea, TSP, MoP and gypsum were applied @500, 2.0, 0.9, 1.2 and 0.75 g Pot^{-1}, respectively in each pot for normal growth and development of *A. vera* seedlings. For integrated experiment, inorganic fertilizer (IF) consisting of urea, TSP, MoP and gypsum @150, 80, 120, 30 kg ha^{-1}, respectively (Biswas, 2005) and PM @ 5 t ha^{-1} was applied during pot preparation. Eight kg processed soil was taken in each earthen pot of 23 cm in height with 30 cm diameter at the top and 18 cm diameter at the bottom. The pot was filled by soil leaving 3cm from the top and labeled with permanent marker. Distilled water was added in each pot, covered with polyethylene and kept for one week before transplanting.

3.5 Test crop

The test crop used in the experiment was *Aloe vera* L. Eighteen months old *A. vera* seedlings were collected from a local farm of *Shomvogonj*, Mymensingh and used for the experiments.

3.6 Experimental design: Complete randomized design (CRD) with three replications.

Fig. 3.1 Some photographs of different forms of *A. vera*

3.7 Experimental details

3.7.1 Expt.1 Screening of suitable soil for *A. vera* cultivation in Bangladesh

Treatments Eight soils of seven soil types were considered as treatments which were as follows.

Sl. No	Soil type	Location
1.	Acid soil	*Fulbaria* (Mymensingh)
2.	Calcareous soil	*Sadar* (Natore)
3.	Non-calcareous soil	Agronomy Field Lab. (BAU, Mymensingh)
4.	*Charland* soil	*Melandoho* (Jamalpur)
5. a)	Saline soil 1 (6.32 dS m^{-1})	*Chokrakhali, Botiagata* (Khulna)
b)	Saline soil 2 (8.14 dS m^{-1})	*Gamramari, Botiagata* (Khulna)
6.	Peat soil	*Kotalipara* (Gopalgonj)
7.	Acid sulphate soil	*Pekua* (Cox’s Bazar)

Total number of pots: 8 soil × 3 replication = 24; Two saline soils of different salinity instead of one were used.

Depending on the results of soil screening experiment (Expt. 1), acid soil for *A. vera* cultivation was selected for Expt. 2 considering the socio-economic conditions of the farmers.

3.7.2 Expt. 2 Integrated effects of inorganic fertilizers (IF) and poultry manure (PM) on the growth, leaf biomass yield, nutrient uptake and pharmaceutical compounds of *A. vera*

Treatments

Poultry manure (PM) is rich in nutrients, which can provide a major source of nitrogen (N), phosphorus (P) and trace elements for crop production. It often contains much higher nutrients than traditional organic fertilizers (Alam *et al*., 2007). The availability of this material is higher compared to other organic manures like farm yard manure, cow dung, green manure etc. That is why PM was used in this experiment.

The following treatments was used for this experiment

Treatment	Inorganic fertilizer	Organic fertilizer
IF_0PM_0	0%	0%
$IF_{100}PM_0$	100%	0%
$IF_{75}PM_{25}$	75 %	25%
$IF_{50}PM_{50}$	50%	50%
$IF_{25}PM_{75}$	25%	75%
IF_0PM_{100}	0%	100%

Treatment: 6, Replication: 3; Total number of pots: 18

IF consisting of N, P, K and S @150, 80, 120, 40 kg ha^{-1} from Urea, TSP, MoP and gypsum, respectively and PM @ 5 t ha^{-1} (Biswas, 2010).

Table 3.1 Total nutrient concentrations of PM and CD used in the experiments

Organic materials	Nutrient concentrations (%)						
	OC	N	P	K	S	Ca	Mg
Poultry manure	16.86	2.20	1.72	0.42	0.27	0.21	0.016
Cow dung	24.03	1.05	0.35	0.45	0.24	0.16	0.015

3.8 Fertilizer application

Well decomposed poultry manure and inorganic fertilizers were applied in each pot as per treatments. One-third amount of urea and full doses of PM and other fertilizers were applied one day before transplanting. The rest two installments of urea were applied at 60 and 120 days after planting (DAP).

3.9 Planting Eighteen months old one *A. vera* seedling was planted in each pot. Planting was done during last week of May, 2017 for soil screening experiment, and 2nd week of October, 2017 for integrated experiment, respectively.

3.10 Irrigation: It was scheduled as and when necessary.

3.11 Soil loosening: Soil loosening was done whenever necessary.

3.12 Weed control: Hand weeding was done time to time as per demand.

3.13 Harvesting and cleaning

A. vera was harvested at 120 and 180 DAP of experiment 1 and 2, respectively. Leaves were collected carefully and cleaned with tap water followed by distilled water to remove soil and other foreign materials. Paper towel was used to remove adhering water.

3.14 Observations recorded

In order to understand the growth and development of *A. vera* plant, specific growth and yield parameters were studied. These have been briefly described under the following heads and sub-heads.

3.15 Growth and yield components

3.15.1 Plant height

Height of the plant was measured in centimeter (cm) from ground to base of the fully opened leaf. The plant height was recorded at harvest.

3.15.2 Leaves plant^{-1}

Total number of leaves was recorded at harvest.

3.15.3 Leaf area plant^{-1}

After harvest, 3 leaves were randomly selected from each pot and mean leaf area was obtained by multiplying leaf length and breadth (expressed in cm^2).

3.15.4 Fresh leaf weight

Fresh leaf weight was recorded and expressed in g plant^{-1}.

3.15.5 Fresh leaf gel weight

Fresh gel weight was recorded and expressed in g plant^{-1}.

3.15.6 Dry leaf weight

Weight of dried leaf was recorded and expressed in g plant^{-1}.

3.16 Mineral nutrient and biochemical parameters

1. Concentration and uptake of mineral nutrients (N, P, K, S, Ca, Mg, Fe, Zn and Mn)
2. Protein content
3. Total phenolic concentration
4. Total flavonoid concentration
5. Total aloin concentration
6. Chlorophyll (a and b) concentration

Nutrient uptake was calculated using the following formula

$$\text{Uptake (mg/g plant}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)}}{100} \times \text{dry weight (mg/g plant}^{-1}\text{)}$$

Protein content was computed by multiplying N concentration of *A. vera* leaf by a conversional factor of 5.85 as described by Jackson (1973).

$$\text{Protein content (\%)} = \text{N (\%)} \times 5.85$$

3.17 Soil analyses

Physical and chemical properties were analyzed following the procedure illustrated here.

Table 3.2 Physical analyses of soils

Name of parameter	Methods
1. Colour	Munsells colour chart (Munsell 1975)
2. Texture	Hydrometer method (Black, 1965). The textural class was determined using Marshall's Triangular Coordinates of USDA system.
3. Bulk density	Core sampler method (Black, 1965)
4. Particle density	Volumetric flask method (Black, 1965)
5. Moisture content	Pressure plate apparatus method (Black, 1965)

Table 3.3 Chemical analyses of soils

Parameter	Methods
1. pH	Glass-electrode pH meter, the soil water ratio being 1: 2.5 as described by (Jackson, 1962).
2. EC	Glass electrode method (Anderson and Ingram, 1996)
3. Organic C	Wet digestion method (Nelson and Sommers, 1982). The amount of organic matter was calculated by multiplying the percent organic carbon with the van Bemmelen factor 1.73 (Piper, 1950).
4. Total N	Micro-Kjeldahl method (Bremner and Mulvany, 1982). Soil sample was digested with conc. H_2SO_4 in presence of K_2SO_4 catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 10:1:0.1). Nitrogen in the digest was determined by distillation with NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with H_2SO_4.
5. Available P	pH value up to 6.5, Bray & Kurtz method (Bray *et al*., 1945). Extracted by NH_4F and determined colorimetrically using molybdate blue ascorbic acid method (Olsen and Sommers, 1982) pH value greater than 6.5, Olsen method. Extracted by $NaHCO_3$ (pH 8.5) solution and determined colorimetrically using molybdate blue ascorbic acid method (Olsen and Sommers, 1982)
6. Exchangeable K, Ca and Mg	K was extracted by ammonium acetate extraction method (Coleman *et al*., 1959) and determined by flame photometer as outlined by Knudsen *et al*. (1982). Ca & Mg concentration was determined by complexometric method of titration using Na_2EDTA as a complexing agent (Page *et al*., 1982).
7. Available S	Extracted by $CaCl_2$ solution and determined turbidimetrically using $BaCl_2$ crystals (Fox *et al*., 1964).
8. Available B	Hot water extraction method (Page *et al*., 1982) and determined by spectrophotometer using azomethine-H (Keren, 1996).
9. Available Cu, Fe, Mn and Zn	DTPA extraction method. Extracted by DTPA solution + TEA + $CaCl_2$ solution (soil: DTPA ration 1:10) and measured by atomic absorption spectrophotometer (Model UNICAM 969, England) (Lindsay and Norvell, 1978).

3.18 Chemical analyses of *A. vera* leaf

3.18.1 Preparation of samples

3.18.1.1 Pre-extraction activities

For preparing the extraction, the fresh leaf was chopped, washed, and cut from the middle. The gel was separated by scraping it with a spoon. Leaf gel was oven dried at 70^0C for 48 hours and finally yellow/orange powder obtained. Powdered samples were preserved in polythene bag and kept in refrigerator. Just before extraction, the preserved sample was taken out from the refrigerator left out at room temperature and then placed in an oven at 40^0C for 1 hour. Requisite quantity of powdered *A. vera* gel was weighed accurately and taken for extraction.

3.18.1.2 Digestion of leaf samples with H_2SO_4 for total N determination

Powdered leaf gel sample was digested with conc. H_2SO_4 in presence of K_2SO_4 catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 10:1:0.1). Nitrogen in the digest was collected by distillation with NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with standard H_2SO_4.

3.18.1.3 Preparation of *A. vera* leaf gel extract for the determination of mineral concentrations

Exactly 1g of leaf gel powder was taken into a 250 mL conical flask and 10 mL of di-acid mixture (HNO_3:$HClO_4$ = 2:1) was added to it. Then it was placed on sand bath until the solid particles disappeared and milky dense white fumes were evolved from the flask. Then it was cooled at room temperature, washed with distilled water and filtered into 100 mL volumetric flasks through Whatman No. 42 filter paper making the volume up to the mark with distilled water following wet oxidation method as described by Jackson (1973). The extract was used for the determination of P, K, S, Ca, Mg, Fe, Mn, Zn and B.

3.18.2 Mineral nutrient determination

All the mineral nutrients were determined following standard methods as described in Table 3.2.

3.18.3 Determination of chlorophyll concentration

3.18.3.1 Extraction of chlorophyll (Arnon, 1949)

Chlorophyll concentration was determined following the method proposed by Arnon (1949). Two hundred milligrams of dried leaf powder was treated with 10 mL of 80%

acetone at 4^{o}C and centrifuged at 2500 rpm for 10 minutes at 4^{o}C. Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 645 and 663 nm with spectrophotometer (Model: TG-60 U, UK).

3.18.3.2 Calculation of chlorophyll concentration

The concentrations of chlorophyll a and chlorophyll b were calculated using the following equation:

Chlorophyll a: 12.7(A663) – 2.69(A645)

Chlorophyll b: 22.9(A645) – 4.68(A663)

3.18.4 Determination of pharmaceutical compounds

For preparing the extraction, the fresh leaf was chopped, washed, and cut from the middle. The gel was separated by scraping it with a spoon. It was homogenized in a blender and then conserved at -20°C (Ozsoy *et al*., 2009).

3.18.4.1 Total phenolic and flavonoid concentrations

3.18.4.1.1 Extraction

Exactly 20 g of each sample was soaked with methanol for 72 h. The filtrates were concentrated using rotary evaporator at 40^{o}C. The dried extract was weighed and store at -4^{o}C.

3.18.4.1.2 Determination of total phenolic concentration

Total phenolic concentration was determined by the Folin-Ciocalteau method (Singleton and Rossi 1965). Gel extract was mixed with Folin-Ciocalteu reagent for 5 minutes and then the aqueous Na_2CO_3 was added. The mixture was allowed to stand for 30 minutes, and the phenols were determined by colorimetric method at 765 nm. Values were expressed in terms of Gallic acid equivalent (mg g^{-1} of fresh weight). All samples were analyzed in triplicates.

3.18.4.1.3 Determination of total flavonoid concentration

Total flavonoid concentration was determined following colorimetric aluminum chloride method as described by Dewanto *et al.* (2002). Briefly, 0.5 mL solution of leaf gel extract was mixed with 1.5 mL of methanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M potassium acetate, and 2.8 mL of distilled water separately. The mixture was left for 30 minutes at room temperature and the absorbance of the mixture was measured at 415 nm with a spectrophotometer (Model: TG-60 U, UK). Total Flavonoid concentration was expressed as quercetin equivalents (mg 100 g^{-1} of fresh weight). Triplicate reading were taken and the result averaged.

3.18.4.2 Determination of total aloin concentration

Aloin concentration was determined by using the method of McCarthy and Mapp (1970). In the filtered juice, 1% $Ca(OH_2)$ was added and centrifuged. After the centrifugation, residues containing aloin settle down. Then supernatant was decanted and residues were weighed. Aloin concentration of leaves were determined and expressed as µg g^{-1} fresh weight.

3.19 Statistical analyses

The record data were subjected to statistical analysis. All the data were analyzed for ANOVA with the help of a computer package program of MSTAT (Mathematical and Statistical Calculation). A one way ANOVA was made by F variance test. The pair comparisons were performed by Duncan's Multiple Range Test (DMRT) at 5% and 1% level of probability (Gomez and Gomez, 1984).

3.20 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of poultry manure and inorganic fertilizer. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 8% for one year. The market price of *A. vera* was considered for estimating the cost and return. The benefit cost ratio (BCR) was calculated as follows:

BCR = Gross return per hectare (Tk.)/Total cost of production per hectare (Tk.)

3.21 People's perception regarding the medicinal and economic importance of *A. vera*

A survey was conducted in early 2018, to assess the basic knowledge regarding medicinal and economic importance of *A. vera* among the personnel related to *A. vera* in Mymensingh district of Bangladesh. This study was conducted on users, farmers and hawkers of *A. vera*. A sample size of 60 individuals was considered sufficient**.**

3.21.1 Preparation of questionnaire for data collection

A questionnaire was prepared to assess the people's perception to the medicinal and economic importance of *A. vera* containing both open and closed form of questions. Simple direct question and statement were included in the questionnaire for collecting information regarding *A. vera*. No unambiguous and double question was included in the schedule. The questionnaire was translated into Bengali version for easy understanding to both the interviewer and the interviewees. The interview schedule was administrated to 10 respondents for field test in non-study area. Based on the feedback of the field test necessary correction, modification, alternation and adjustment were made to finalize the questionnaire for final data collection. An English version of the questionnaire has been presented in the Appendix-6.

3.21.2 Collection of data for questionnaire

Data were collected from 60 randomly selected respondents by the questionnaire through face to face interview during the leisure period of the respondents. For data collection, good rapport was established with the respondents so that they did not hesitate to furnish proper responses of the question and statement. If any respondents felt difficulty about a statement the researcher explained and clarified that easy enough to understand by the respondents as clear as possible**.** Data from the questionnaires were compiled by converting the qualitative data into quantitative forms by appropriate scoring techniques. The responses of the respondents that were recorded in the questionnaires were tabulated in a master sheet for entering them into the computer. Then the tabulated data were entered into the computer and analysis was done in accordance with the objectives of the study using Microsoft Office 2010. Various statistical measures such as range, mean and percentage were used to describe the selected characteristics of the respondents.

CHAPTER 4

RESULTS AND DISCUSSIONS

Two experiments were conducted sequentially in the green house of BINA and open net house of the department of Agricultural Chemistry, Bangladesh Agricultural University, during 2017–2018 to find out the most suitable soil (s), optimum combination of inorganic fertilizer and poultry manure (PM) for *A. vera* cultivation, integrated effects of inorganic fertilizer and PM on leaf biomass yield, nutrient uptake, pharmaceutical compounds of *A. vera* and post-harvest fertility of soil. The economics of *A. vera* cultivation under different treatments and public perception regarding the medicinal and commercial importance of this plant was also studied.

4.1 Experiment 1: Screening of suitable soil for *A. vera* cultivation in Bangladesh

Soils of different types affect crop production according to their capability as a nutrient supplier based on plant requirement. Incorporation of *A. vera* into agricultural production systems depends upon details information regarding the plant, suitability of soil, its agronomic potentiality and nutritional requirements. Seven different types of soils were selected to find out the most suitable soil for *A. vera* cultivation in Bangladesh.

4.1.1 Physico-chemical properties of soils

The physical properties of different soil types under investigation have been presented in Table 4.1. Results reveal that majority of the soils were light grey in colour except acid and peat soil which were reddish and blackish, respectively. Most of the soils were clay to clay loam in texture except non-calcareous and *charland* soil which were sandy clay loam to loam. Bulk density, particle density and moisture content varied with respect to soils and ranged from 1.23-1.45 g cc^{-1}, 2.20-2.58 g cc^{-1} and 27.07-30.20%, respectively.

Chemical properties also varied across the soils (Table 4.2). pH, EC and organic matter content ranged from 3.87-7.80, 0.25-14.04 dS m^{-1} and 0.88-16.40%, respectively. Total N, exchangeable K, available P and S concentrations ranged from 0.05-0.95%, 0.17-0.73 cmol kg^{-1} soil, 3.09-12.10 and 11.06-735.12 μg g^{-1} soil, respectively.

Table 4.1 Physical properties of different soil types used for *A. vera* cultivation

Types of soil	Colour	Texture	Bulk density (g cc^{-1})	Particle density (g cc^{-1})	Moisture content (%)
Acid	Reddish	Clay	1.23	2.25	29.86
Calcareous	Light grey	Clay loam	1.42	2.51	28.12
Non calcareous	Light grey	Sandy clay loam	1.45	2.58	27.07
Charland	Light grey	Loam	1.44	2.54	27.15
Saline 1	Light grey	Clay	1.25	2.23	29.72
Saline 2	Light grey	Cay	1.24	2.20	30.20
Peat	Blackish	Clay loam	1.41	2.52	28.34
Acid sulphate	Light grey	Clay	1.28	2.24	29.55

Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}.

Table 4.2 Chemical properties of different soil types used for *A. vera* cultivation

Types of soil	pH	EC (dS m^{-1})	OM (%)	Total N (%)	Avail. P (µg g^{-1})	Exch. K (cmol kg^{-1})	Avail. S (µg g^{-1})
Acid soil	5.20	0.25	1.58	0.09	3.09	0.20	11.80
Calcareous	7.50	1.26	1.40	0.07	4.86	0.19	15.78
Non calcareous	6.75	0.68	1.83	0.12	12.10	0.17	11.06
Charland	7.00	0.61	0.88	0.05	6.91	0.18	19.50
Saline 1	7.50	6.32	1.97	0.11	5.89	0.41	35.20
Saline 2	7.80	8.14	2.51	0.15	6.90	0.44	43.47
Peat	5.70	4.09	16.40	0.95	3.12	0.73	641.40
Acid sulphate	3.87	14.04	2.45	0.14	4.72	0.22	735.12

Avail. = Available, Exch. = Exchangeable, Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}.

4.1.2 Effects of different soil types on the growth and leaf biomass yield of *A. vera*

The data pertaining to the effects of different soil types of Bangladesh on the growth, leaf yield and yield contributing characters of *A. vera* are described below.

4.1.2.1 Plant height

A. vera is a semi subtropical plant that is grown easily like any other vegetable crop (McKeown, 1987). Aloe is grown in all kinds of soil with high organic matter content (Kent, 1980). Data on the effects of different soil types on plant height of *A. vera* have been presented in Table 4.3. Soil types significantly influenced the height of *A. vera* plant at harvest. Highest height (44.03 cm) was recorded from the plant grown in non-calcareous soil which was statistically identical with those plants grown in acid soil (40.37cm), calcareous soil (41.73 cm) and *charland* soil (39.53 cm) but significantly different from the plants grown in saline, peat and acid sulphate soils. Saline and peat soils produced statistically similar heighted plants. The lowest plant height (23.17 cm) was recorded from the plant grown in acid sulphate soil. Zaman (2015) also reported lowest plant height of stevia grown in acid sulphate soil.

Table 4.3 Effects of different soil types on the growth and leaf biomass yield of *A. vera*

Soil types	Plant height (cm)	Leaves plant^{-1} (no.)	Mean leaf area plant^{-1} (cm^2)	Dry leaf weight (g plant^{-1})
Acid	40.37±4.50a	11.33±0.58a	245.97±22.9a	133.4±5.4a
Calcareous	41.73±3.82a	10.89±1.15ab	255.57±3.3a	136.0±6.1a
Non-calcareous	44.03±4.58a	12.67±2.52a	262.70±18.3a	132.3±13.1a
Charland	39.53±3.55a	8.33±1.53b	200.67±16.4b	80.5±10.0b
Saline 1	30.73±3.69b	5.67±1.53c	181.89±12.3bc	39.7±2.0c
Saline 2	28.37±3.21bc	5.00±1.00c	170.21±15.6cd	30.3±0.9c
Peat	25.86±2.65bc	4.00±1.00c	166.54±14.5cd	18.3±3.0d
Acid Sulphate	23.17±2.42c	4.33±1.53c	144.38±8.3d	16.3±0.8d
CV%	10.60	19.01	7.40	9.06
$LSD_{0.05}$	6.28**	2.52**	26.06**	11.51**

Means within the same column followed by different letter(s) were significantly different according to DMRT (**P<0.01), Values are mean ± SD; Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}. LSD= Least significant difference; CV= Coefficient of variance.

4.1.2.2 Leaf number

The number of leaves plant^{-1} at harvest differed significantly due to the influence of different soil types of Bangladesh (Table 4.3). The highest number of leaves plant^{-1} (12.67) was counted from the plant grown in non-calcareous soil which was identical with the number of leaves of the plant grown in acid (11.33) and calcareous (10.89) soils. The plants of calcareous (10.89) and *charland* (8.33) soils produced identical number of leaves. Saline soils of 6.32 dS m^{-1} and 8.14 dS m^{-1} also produced identical number of leaves $plant^{-1}$. The lowest number of leaves (4.00) was harvested from the plant grown in peat soil which was statistically identical with those plants grown in saline and acid sulphate soils (4.33). Better performance of non-calcareous and calcareous soils may be due to their moderate pH, less water holding capacity, good soil texture and higher nutrient contents compared to other soils. Similarly acid soil having pH less than 7, strongly acid in reaction with moderate status of organic matter, low moisture holding capacity (BARC, 2005) could be the reasons for getting better yield.

4.1.2.3 Leaf area

The data pertaining to leaf area $plant^{-1}$ at harvest as influenced by different soil types of Bangladesh are presented in Table 4.3. Mean leaf area $plant^{-1}$ was significantly affected by different soil types. Maximum leaf area (262.70 cm^2) was measured from the plant grown in non-calcareous soil which was identical with the leaf area of the plants grown in acid (245.97 cm^2 $plant^{-1}$) and calcareous (255.57 cm^2 $plant^{-1}$) soils. *Charland* (200.67cm^2) and saline 1 (181.89 cm^2) soils produced identical leaf area $plant^{-1}$. Saline soil at all levels and peat soil also produced identical leaf areas $plant^{-1}$. The minimum leaf area (144.38 cm^2) was obtained from the plant grown in acid sulphate soil which was identical with the plants grown in saline 2 (170.21 cm^2) and peat soils (166.54 cm^2). These findings were in good agreement with the results reported by Zaman (2015) and Khanom (2007) for stevia.

4.1.2.4 Fresh leaf weight

Soil types had significant effects on leaf fresh weight of *A. vera* (Fig. 4.1 and Appx. 1). The highest leaf fresh weight was calculated from the plant grown in non-calcareous soil (1948 g $plant^{-1}$) which was statistically non-significant with the fresh weight of the plant grown in acid (1768 g $plant^{-1}$) and calcareous (1896 g $plant^{-1}$) soils. The lowest fresh weight was obtained from the plant grown in acid sulphate soil (233 g $plant^{-1}$) which was identical with the fresh weights of the plants grown in peat soil (262 g $plant^{-1}$). Too low pH of acid sulphate soil which in turn reduces nutrient availability and very OM content of peat soil may cause nutrient toxicity could be the prime reason of getting lowest yield of *A. vera*. Soil provides physical support to plant as well as supplies necessary water and nutrient elements for plant growth and development. Plant growth basically depends on the physical, chemical and biological properties of soil. Khanom (2007) cultivated stevia in four different soils of Bangladesh *viz.* calcareous, non-calcareous, acid and saline. She reported that non-calcareous soil was the best performer followed by acid soil for the growth and leaf yield of stevia. The result coincided with the present study.

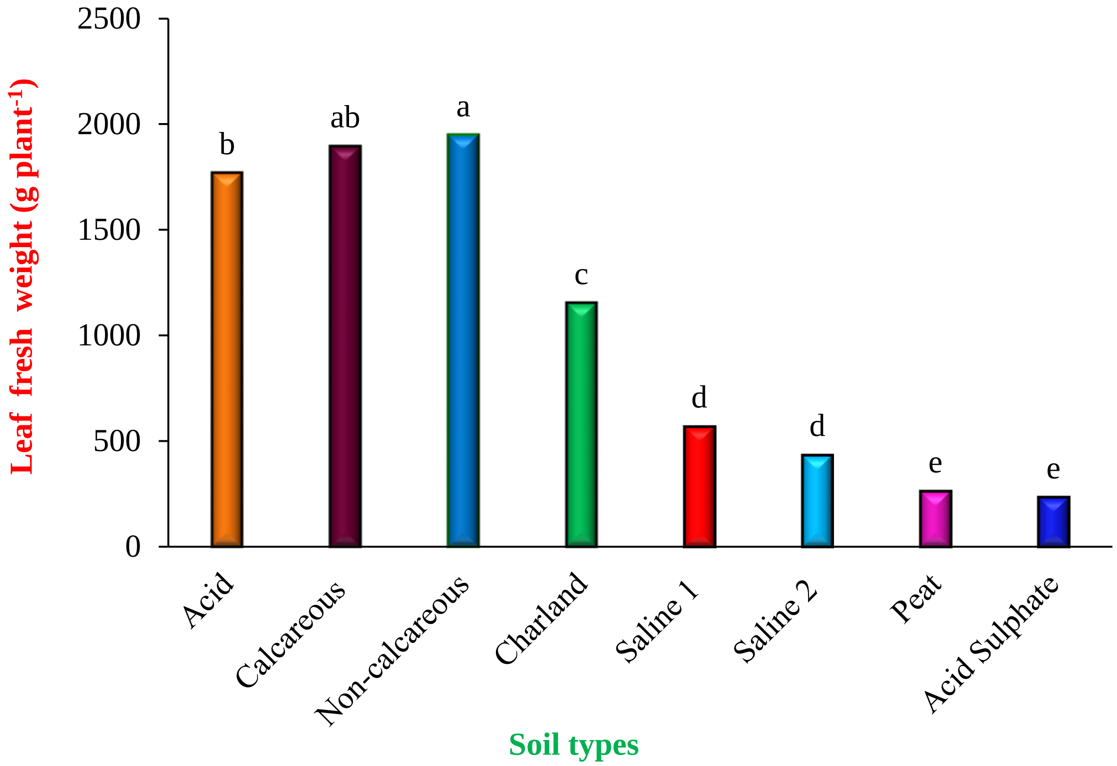


Fig.4.1 Effects of different soil types on the leaf fresh weight of *A. vera*
Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}.

4.1.2.5 Fresh leaf gel weight

A statistically significant variation was noticed in terms of fresh leaf gel weight of *A. vera* due to the differences in soil types (Fig. 4.2 and Appx. 2). The highest fresh leaf gel weight (997 g $plant^{-1}$) was obtained from the plant grown in calcareous soil which was identical with the gel weight (880 g $plant^{-1}$) of the plant grown in acid soil. Better performance of acid soil may be due to having pH less than 7, strongly acid in reaction with moderate status of organic matter, low moisture holding capacity (BARC, 2005). The fresh gel weights of the plants grown in acid (880 g $plant^{-1}$) and non-calcareous (859 g $plant^{-1}$) soils were also identical. The lowest fresh gel weight was obtained from the plant grown in peat soil (192 g $plant^{-1}$) which was not supported by the result reported by Rahi *et al.* (2013) on *A. vera* grown in sodic soil. Very poor performance of peat soil may be due to its high organic matter content (>20%) and water saturated environment (Khan *et al.*, 2008). The poor performance of acid sulphate soil mainly could be due to its very low pH (3.9).

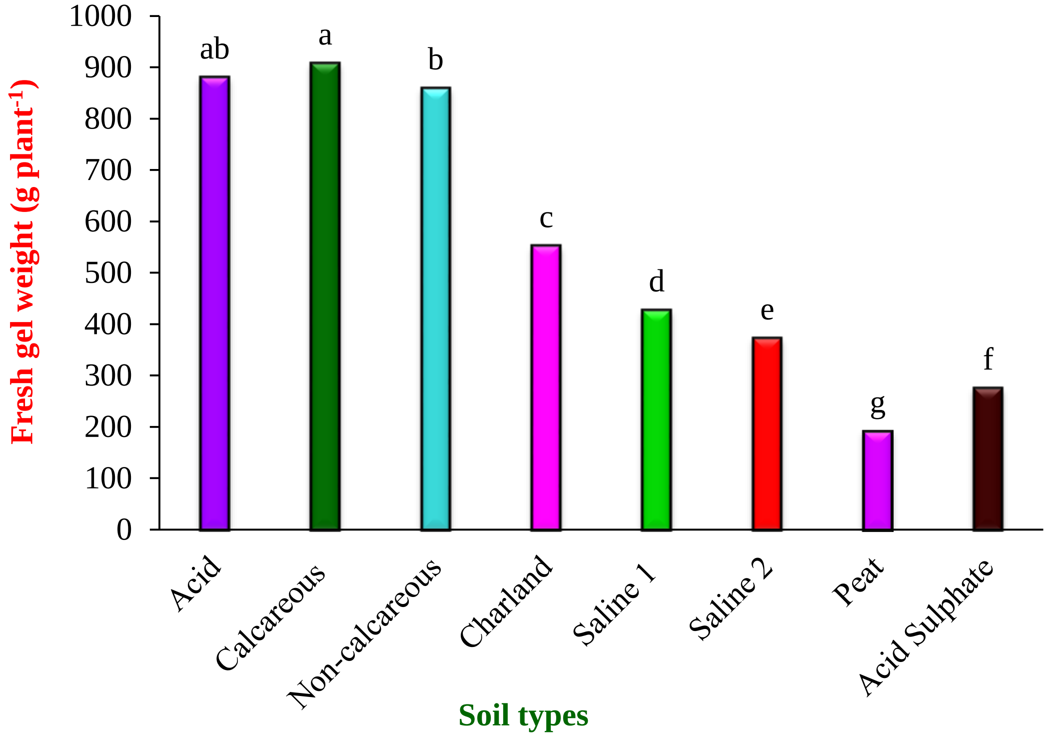


Fig. 4.2 Effects of different soil types on the leaf fresh gel weight of *A. vera*
Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}.

4.1.2.6 Dry leaf weight

The dry weight of *A. vera* leaves varied significantly due to the differences in soil types (Table 4.1). The highest leaf dry weight was obtained from the plant grown in calcareous soil (136.0 g $plant^{-1}$) which was identical with the dry weight of the plant grown in acid (133.4 g $plant^{-1}$) and non-calcareous (132.3 g $plant^{-1}$) soil. The dry weight of the plant grown in *charland* soil was 80.5 g $plant^{-1}$. The lowest dry weight was obtained from the plant grown in acid sulphate soil (16.3g $plant^{-1}$) which was identical with the dry weight (18.3g $plant^{-1}$) of the plant grown in peat soil. The dry leaf yield of other soils increase over acid sulphate soil ranged between 12% for the plant of peat soil to 734% for the plant of calcareous soil.

The yield increase of the plants grown in acid, non-calcareous, *charland*, saline 1 and saline 2 were 718, 712, 394, 144and 86%, respectively. Fresh gel yield of *A. vera* grown in

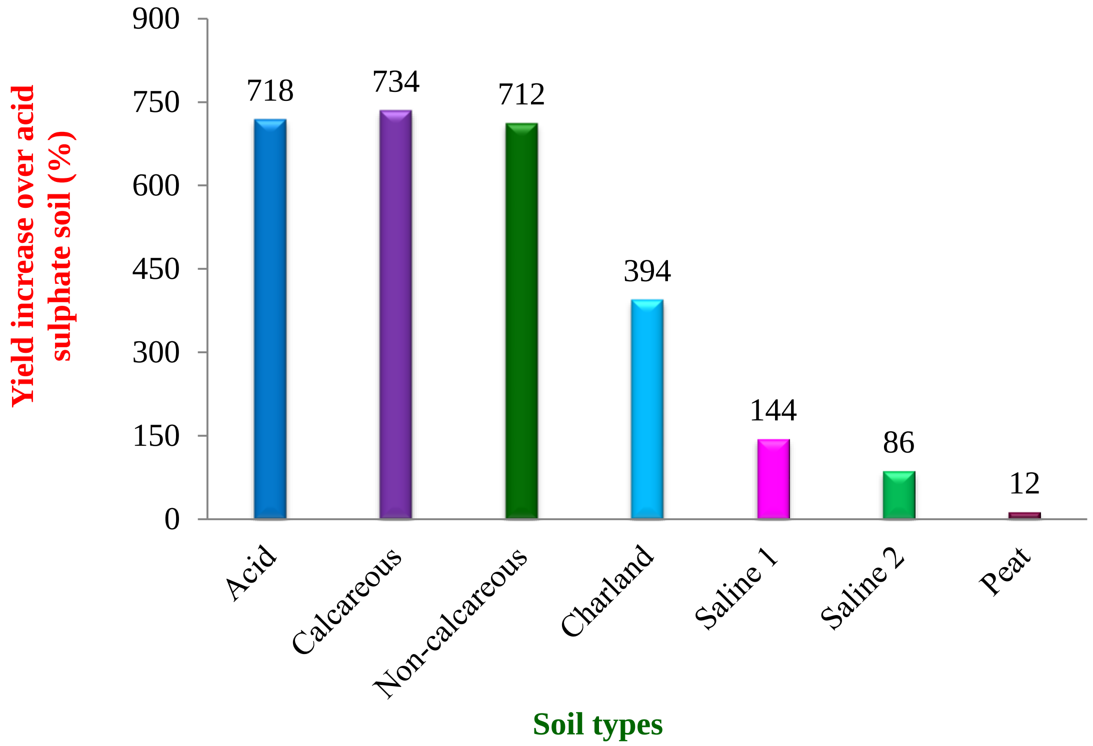


Fig. 4.3 Effects of different soil types on the yield increase over acid sulphate soil of *A. vera*. Saline 1 = 6.32 dS m^{-1}, Saline 2 = 8.14 dS m^{-1}.

different soils of Bangladesh was of the following order Calcareous ≥ acid ≥ non-calcareous > *charland* > saline 1 > saline 2 > peat > acid sulphate soils. Similar result was reported by Zaman (2015) in case of stevia. The performance variation of different soils for *A. vera* cultivation may be due the physical and chemical properties of the soils under investigation. Among the properties, pH, organic matter content, salinity, nutrient contents and their availability are the prime factors controlling the growth and yield of any crop.

4.1.2.7 Correlation between different physical parameters of *A. vera*

Statistical relationships between growth, yield and yield attributes were studied. The correlation and regression lines of these parameters have been shown in Fig. 4.4. The results reveal that the growth and yield parameters *viz.* plant height, number of leaves $plant^{-1}$, mean leaf area (cm^2), fresh leaf weight (g $plant^{-1}$) and fresh gel weight (g $plant^{-1}$) were significantly and positively correlated where correlation coefficients (r) are 0.884*, 0.902**, 0.926**and 0.977**, respectively. The relationships were more evident from the regression equations (y = 76.93x - 1600, y = 76.17x - 14.69, y = 14.79x – 1976 and y = 0.395x + 160.8, respectively) showing gradual increase in fresh leaf and gel weight with increasing plant height, number of leaves $plant^{-1}$, leaf area and fresh leaf weight.

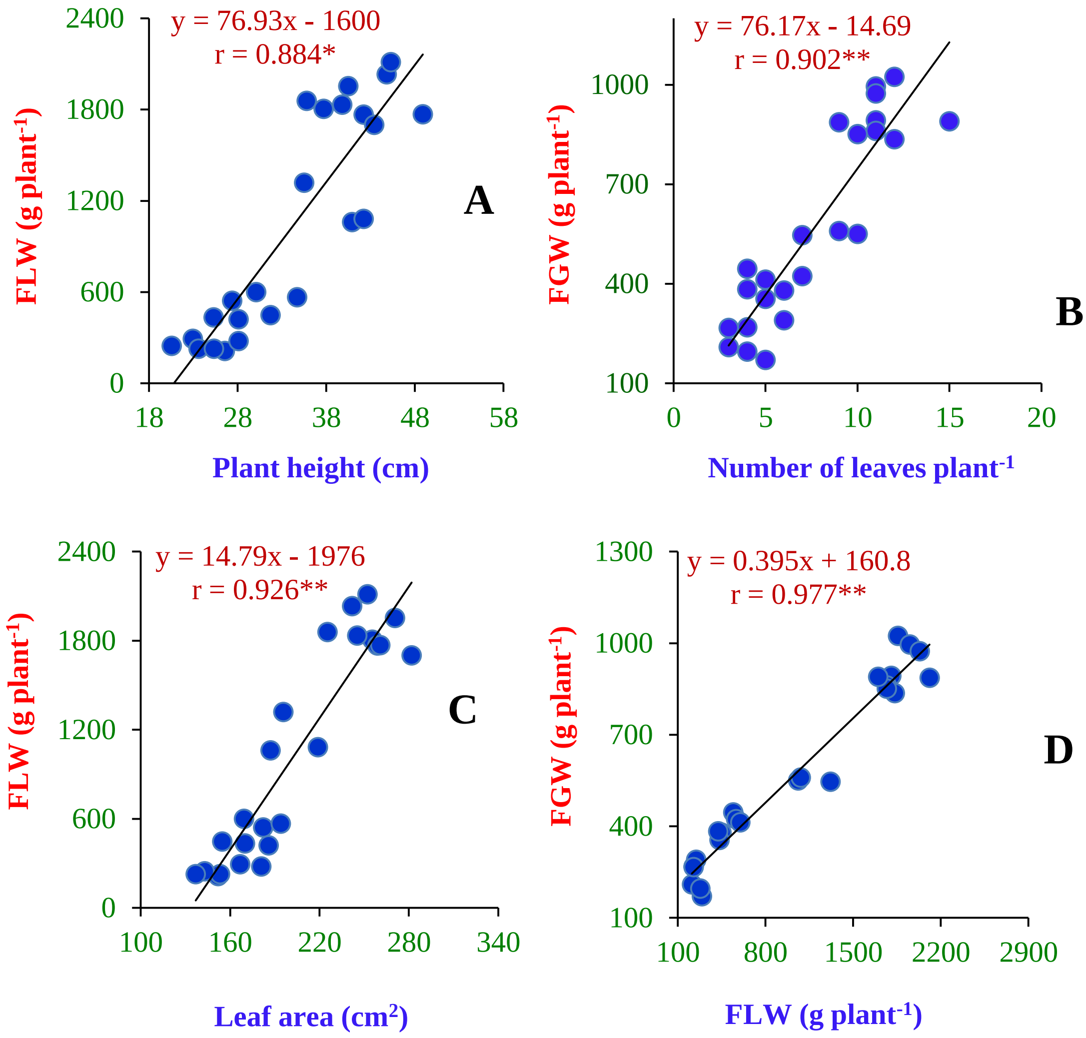


Fig. 4.4 Relationships between (A) plant height and FLW (B) number of leaves plant^{-1} and FGW (C) leaf area and FLW and (D) FLW and FGW of *A. vera* as influenced by different soil types. FLW = Fresh leaf weight, FGW = Fresh gel weight.

4.2 Experiment 2: Integrated effects of inorganic fertilizers (IF) and poultry manure (PM) on the growth, leaf biomass yield, nutrient uptake and pharmaceutical compounds of *A. vera*

Along with the inorganic fertilizers (IF), organic manures can be mixed to the soil to control nutrient deficiency, increase organic matter content, water holding capacity of the soil to stimulate the activity of beneficial microorganisms that makes the plant food elements in the soil readily available to the plants. Organic manures in combination with IF are expected to contribute more to the growth and development of *A. vera* than their sole application. PM along with IF in different combination was evaluated for the growth, leaf biomass yield, nutrient uptake and pharmaceutical compounds of *A. vera*. The results are described here.

4.2.1. Integrated effects of IF and PM on the on the growth, yield attributes and leaf biomass yield of *A. vera.*

4.2.1.1 Plant height

The application of different levels of IF and PM had a significant effect on the plant height of *A. vera* (Table 4.4). Plant height was significantly increased during growth period and reached their maximum values at harvest. The tallest plant (57.14 cm) was identified from the pot treated with $IF_{100}PM_0$ which was identical with $IF_{75}PM_{25}$ treated plants. The shortest plant (35.22 cm) was noted from control (IF_0PM_0) treatment. Plant height was increased by 21.92 cm from $IF_{100}PM_0$ treatments over control. The plants treated with higher doses of inorganic fertilizers had higher plant height than PM treated plants. PM along with IF ensured the availability of other essential nutrients for plant and gave taller plant than control. The result was corroborated with the reports of Farooq *et al.* (2015) that showed increase in plantheight with increase in application of organic fertilizers. It is also in agreement with the finding of Jayathilake *et al.* (2002) who reported highest plant height through the application of organic manures plus 50% N and 100% PK in onion. Kumar *et al.* (2013) noticed that combined application of chemical fertilizer and poultry manure increased the plant height of *A. vera*. In a field study, Khan *et al*. (2012) reported that availability of nutrients increased the biomass of plants. Jin *et al.* (1996) also found increased plant height of red arnaranth due to the application of cattle manure. Similar results were also reported by Koboyoshi *et al.* (1989) applying FYM plus fertilizer N in rice.

Table 4.4 Integrated effects of IF and PM on plant height, number of leaves, mean leaf area and leaf dry weight of *A. vera* at harvest

IF and PM levels	Plant height (cm)	Number of leaves plant^{-1}	Mean leaf area plant^{-1} (cm^2)	Leaf dry weight (g plant^{-1})
IF_0PM_0	35.22±2.73d	10.67±1.5c	284±46	166.16±15.0d
$IF_{100}PM_0$	57.14±2.51a	18.33±1.5a	292±35	414.07±39.18a
$IF_{75}PM_{25}$	51.14±5.89ab	16.0±2.0a	299±33	339.27±28.43b
$IF_{50}PM_{50}$	45.62±3.02bc	14.33±1.5b	297±30	318.04±29.33bc
$IF_{25}PM_{75}$	48.54±7.35bc	18.0±2.6a	332±37	420.70±24.87a
IF_0PM_{100}	41.42±3.88c	12.67±2.1b	334±18	273.97±32.43c
CV%	9.04	12.86	11.19	9.05
$LSD_{0.05}$	7.48**	3.44*	NS	51.86**

IF= Inorganic fertilizers; PM=Poultry manure; NS= not significant. Means within the same column followed by the different letter(s) were significantly different according to DMRT **P<0.01; *P<0.05), Values are mean ± SD; LSD= Least significant difference; CV= Coefficient of variance.

4.2.1.2 Leaf number

The data pertaining to the leaf number of *A. vera* as influenced by the integrated effects of IF and PM are presented in Table 4.4. Leaf number of the plants differed significantly due to the application of different levels of IF and PM. A rapid and tremendous increase in leaf number was observed in the plant fertilized with $IF_{100}PM_0$ treatment followed by $IF_{25}PM_{75}$ and $IF_{75}PM_{25}$. However, the highest number of leaves plant^{-1} was counted from the plant treated with $IF_{100}PM_0$ which was statistically identical with $IF_{25}PM_{75}$ and $IF_{75}PM_{25}$ but different from other treatment combinations. In contrast, the lowest number of leaves was observed in the plant neither receiving PM nor IF. The growth of the plants of the control treatment tended to be stunted and produced fewer leaves than fertilized pots. Except control, among other treatment combinations, the lowest number of leaves was counted from the plant fertilized with IF_0PM_{100} and $IF_{50}PM_{50}$ which was significantly different from other treatments.

From this study it was observed that the application of $IF_{100}PM_0$, $IF_{75}PM_{25}$ and $IF_{25}PM_{75}$ increased leaf number by 72%, 69% and 50% over control, respectively. Mean leaf number was increased by 49% over control. The production of greater number of leaves could be due to higher metabolic activity because of the higher availability of macro and micro nutrients from PM and NPKS resulting in higher production of carbohydrates and phytohormones which were manifested in the form of enhanced growth as explained by Govindan and Purushottam (1984). Enhanced leaf parameters with increased levels of fertilizers were also reported (Maheshwar, 2005 and Khanom *et al.,* 2008). This is also identical with Zaman *et al.* (2017), where the increased leaf number was achieved in stevia due to the combined application of higher levels of poultry manure and integrated chemical fertilizers.

4.2.1.3 Leaf area

Leaf area is used to predict primary photo synthate (compound) production, evapo-transpiration and as a reference tool for crop growth. Leaf area plays an essential role in theoretical production ecology (Wilhelm *et al.*, 2000). The application of IF and PM in different combinations had no significant effect on the leaf area of *A. vera* (Table 4.4). The highest leaf area plant^{-1} (334 cm^2) was measured from the plant fertilized with IF_0PM_{100} which was identical with all other combinations of IF and PM along with control. The lowest leaf area plant^{-1} (284 cm^2) was noticed in the plant grown in control (IF_0PM_0). Leaf area was increased by 50 cm^2 across the treatments over control. The result was different from the results reported by Agbede and Adekiya (2012) and Zaman *et al.* (2017). On the other hand Jamir *et al.* (2017) reported that vermicompost in combination with chemical fertilizers increased leaf area of pepper more significantly than poultry manure.

4.2.1.4 Fresh leaf weight

Different combinations of IF and PM had significantly influenced the fresh weight of *A. vera* leaves plant^{-1} at harvest (Fig. 4.4 and Appx.3). Results revealed that fresh weight progressively increased with the different combined levels of IF and PM application up to $IF_{25}PM_{75}$. The highest fresh weight plant^{-1} (4864 g) at harvest was measured from the plant receiving $IF_{25}PM_{75}$ followed by $IF_{100}PM_0$ (4787g) and both of them were identical. Plants treated with $IF_{75}PM_{25}$ and $IF_{50}PM_{50}$ produced 3922 and 3677 g plant^{-1}, respectively. The lowest values were obtained from the control treatment (1921 g plant^{-1}). Fresh weight was increased by 1697 g plant^{-1} over sole application of PM across the treatments. Either sole application of IF or combined application of IF and PM important roles in increasing the leaf fresh and dry weight of any crop. Goussous and Mohammad (2009) reported an increase of leaves fresh weight of *Allium cepa* due to N and P fertilizers.

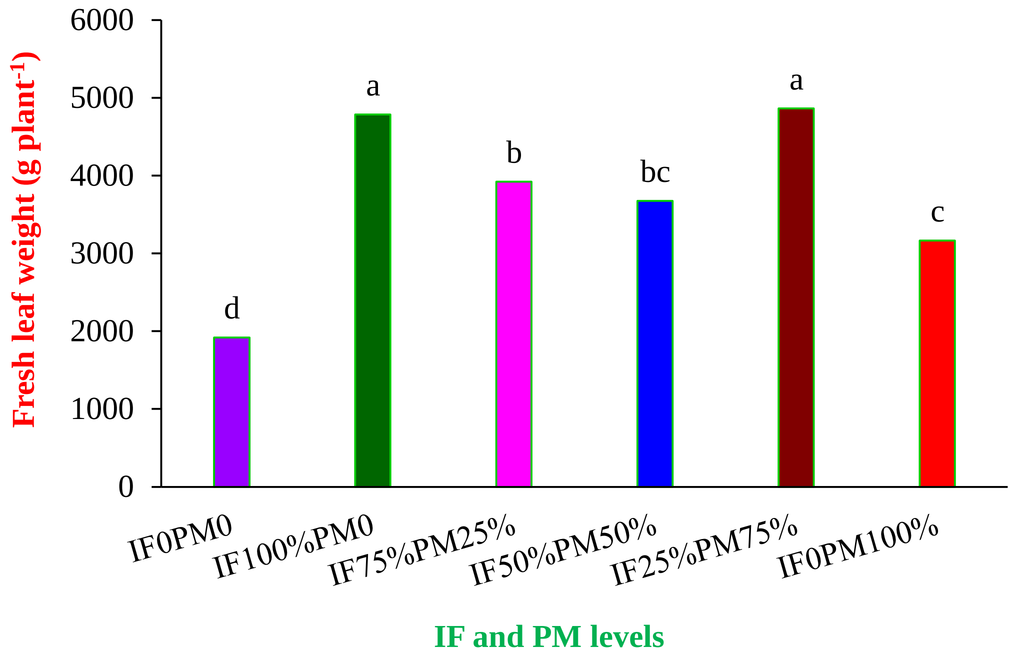


Fig.4.5 Integrated effects of IF and PM on the fresh leaf weight of *A. vera*

Hasanuzzaman *et al*. (2008) showed that organic fertilizers increased leaf fresh weight of *A. vera* and it is in line with the present results. In this context Prabha and others (2007) reported that the weight and plant growth were due to the increased absorption of mineral nutrients such as nitrogen and plant growth regulators. The investigations of Atiyeh *et al.* (2002) had shown that suitable effects of PM occurred due to physical, chemical, biological and microbial characteristics of changing conditions. Also, other causes included pH regulation and a significant increase in water storage capacity of the substrate. On the other hand, the increase in plant height caused the leaf weight to increase. It is effective in increasing the amount of gel. According to Muscolo and his colleagues (1999) it can stimulate hormone production such as auxin. Also, excessive microbial activity increased the concentration of nitrogen in plants (Arancon *et al.*, 2004).

4.2.1.5 Fresh gel weight

Different combinations of IF and PM significantly influenced the fresh gel weight of *A. vera* plant^{-1} at harvest (Fig. 4.5 and Appx. 4). Comparison of data indicates that an increase in PM causes the gel weight to increase as well, so that the maximum gel was showed in $IF_{25}PM_{75}$ and declined with sole application of PM.

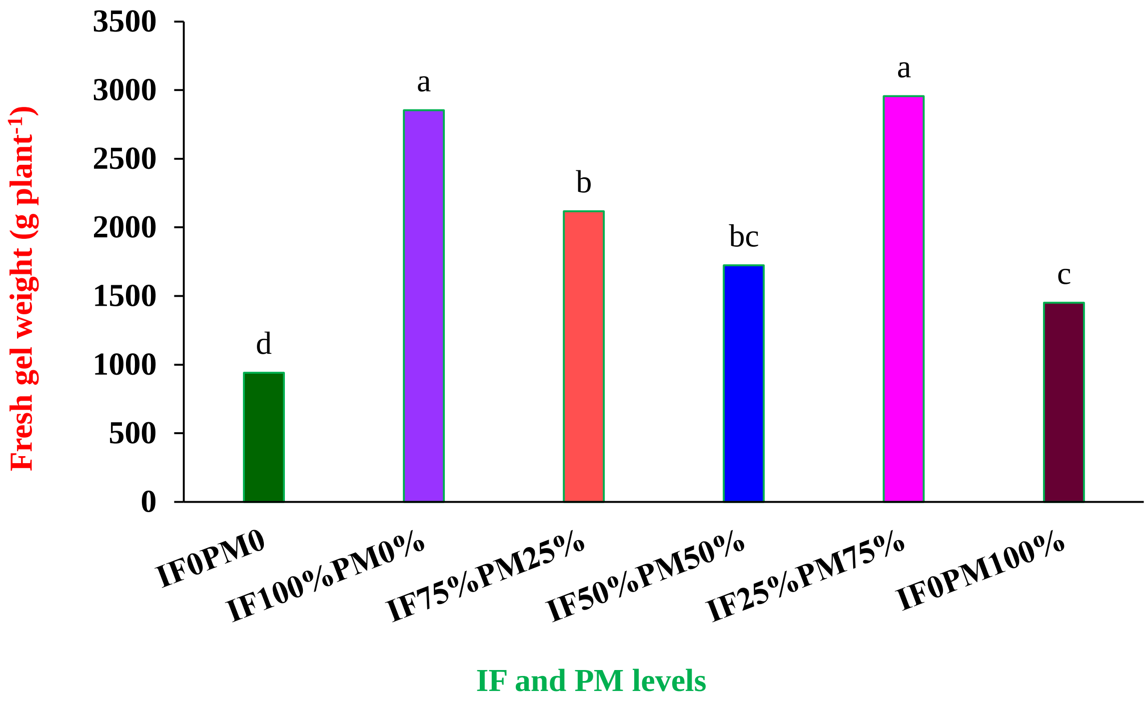


Fig.4.6 Integrated effects of IF and PM on the fresh gel weight of *A. vera*

The highest gel weight plant^{-1} (2956 g) at harvest was measured from the plant receiving PM$_{75}$IF$_{25}$ which was significantly higher than other levels of IF and PM except sole application of IF (2854 g plant^{-1}). Statistically second highest gel weight (2117 g plant^{-1}) was found from the plants treated with IF$_{75}$PM$_{25}$ which was identical with gel weight of the plants treated with combined 50% of IF and 50% of PM. The control treatment had the lowest amount of gel (941 g plant^{-1}). The highest fresh gel weight was increased by 214.13% over control across the treatments.

The experiments by Cruz *et al.* (2002) and Saha *et al.* (2005) and Nematian *et al.* (2010) confirmed that the nutrient minerals, such as N and K, increase leaf growth and lead to a substantial amount of gel in *A. vera*. From inorganic fertilizers plants got nutrients immediately than poultry manure at initial stage but gradually it decreased as the nutrient lost from the soil by various means. On the other hand, application of NPKS and poultry manure together increase the availability of nutrients through out the whole growing period of the plant. The supply of nutrients, such as N, P, K and S, played a significant role in growth and primary metabolism performance. Also based on the carbon balance of minerals hypothesis and growth differentiation hypothesis, there is a characterized bilateral relationship between primary and secondary metabolism.

As the availability of food for the plant increased, the amount of photosynthesis increased as well as the amount of carbon. It causes the increasing amount of carbon and the increase in carbon can be used in the synthesis of primary and secondary compounds which resulted higher gel weight (Watson, 1963; McKey, 1979; Epstein, 1972 and Bryant *et al.,* 1983). Zarandi *et al.* (2011) reported that the fresh and dry weight shoots in *Ocimum basilicum* plant in all organic treatments was significantly higher than the control and chemical treatments.

4.2.1.6 Dry leaf weight

The dry weight of *A. vera* leaves plant^{-1} at harvest varied significantly due the application of different levels of IF and PM (Table 4.4). Results revealed that dry weight progressively increased withincreasing combined levels of IF and PM application. The highest dry weight plant^{-1} (420.70 g) at harvest was measured from the plant receiving $IF_{25}PM_{75}$ which was significantly different from other levels of IF and PM except $IF_{100}PM_0$ (414.07 g plant^{-1}). The lowest value was obtained from the control treatment (IF_0PM_0). Better performance of crops with NPKS fertilizer combined with poultry manure in all the growth characters observed infers that the plant positively responseded to NPKS fertilizer and PM which agreed with earlier finding of Olatunji and Oboh (2012). They reported increased growth and yield of tomato with combined use of organic and mineral fertilizer. The finding in this experiment also corroborated the findings of Li and Mahler (1995) who obtained better vegetative development in wheat, most especially when soil was amended with inorganic and organic materials of low C:N ratio. The better performance of pot with poultry manure + NPK fertilizer corroborated the result of Kang and Balasubramanian (1990), Ogundare (2011) and Asadu and Unagwu (2012). Thse results of present study are also in agreement with the findings of Rajni Rani *et al.* (2001), Rahman *et al.* (2009) and Parvez *et al.* (2008). Poultry manure also demonstrated superior effect in producing straw yield of rice as compared to cowdung and chemical fertilizers. Ahmed and Rahman (1991) reported that the application of organic manure and chemical fertilizers increased straw yield of rice. The leaf yield was 153% higher in respect of combined application of 25% IF and 75% PM than that of control. Leaf dry weight was increased by 65 to 153% over control across the treatments.

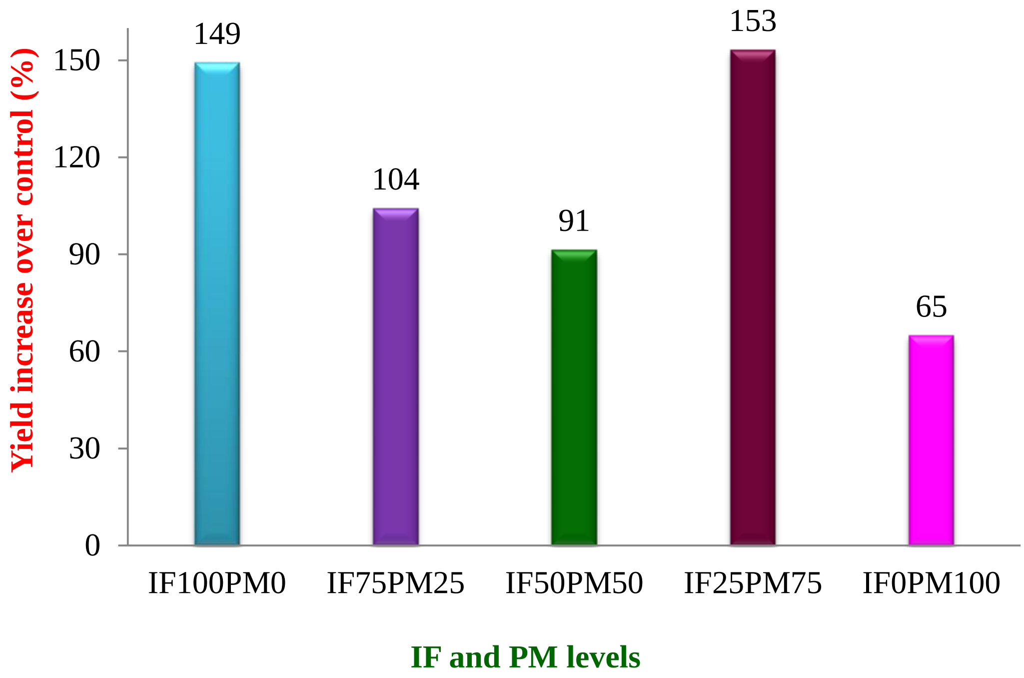


Fig. 4.7 Integrated effects of IF and PM on yield increase over control of *A. vera*

4.2.2 Integrated effects of IF and PM on nutrient concentration, uptake and pharmaceutical compound(s) of *A. vera*

4.2.2.1 Nutrient concentration and their uptake

Effects of integrated fertilizers on mineral nutrient concentrations and their uptake by *A. vera* are given in the Table 4.5 to 4.8. The increase in nutrient concentration was proportional with their rate of application but the nutrient uptake did not follow the same trend. Carbon, Hydrogen and Nitrogen are known as the basic element and most important for living organisms. N is an essential building block of amino acids and nucleic acids. Most of the P in the body is found in the bones and teeth. It plays an important role in how the body uses carbohydrates and fats.

4.2.2.1.1 N concentration and uptake

N concentration of the leaf was significantly affected by different combinations of IF and PM (Table 4.5). The highest concentration (2.71%) was obtained with $IF_{100}PM_0$ which was statistically identical with the N concentration of the leaves of *A. vera* plant fertilized with $IF_{25}PM_{75}$ but significantly different from other treatments. The lowest N concentration was obtained from the plants receiving no fertilizer.

The N uptake by *A. vera* leaf varied from 3.10-11.20 g plant^{-1}. The highest uptake (11.20 g plant^{-1}) was found in sole application of IF which was identical with the 25% IF and 75% PM treated plant and the lowest uptake of 3.10 g plant^{-1} was observed in control treatment. The combination of manure and mineral N fertilizers was reported to improve the total organic N, the microbial biomass N, the labile N, the inorganic N including ammonium (NH_4^+)–N and nitrate (NO_3^-)–N concentrations, the net ammonification, nitrification and N mineralization rate (Gong *et al.*, 2011) through the comparatively prolonged N supply and uptake by plants (Sugihara *et al.*, 2010). This would explain why N uptake was increased by combinations of IF and PM than sole treatments. These results were in line with Abdul *et al.* (2013) and Laxminarayanan (2004) who reported high N uptake with combined application of organic and inorganic fertilizers. Senger *et al.* (2000) and Sharma *et al.* (2000) observed that the application of N fertilizer and manure significantly influenced the N uptake by rice plant.

Table 4.5 Integrated effects of IF and PM on N and P concentrations and their uptake by *A. vera*

IF and PM levels	Nitrogen		Phosphorus	
	Concentration (%)	Uptake (g plant^{-1})	Concentration (%)	Uptake (g plant^{-1})
IF_0PM_0	1.87±0.11d	3.10±0.3d	0.13±0.03d	0.21±0.01d
$IF_{100}PM_0$	2.71±0.14a	11.20±0.8a	0.34±0.04a	1.43±0.28a
$IF_{75}PM_{25}$	2.14±0.16c	7.24±0.2b	0.31±0.02b	1.08±0.22b
$IF_{50}PM_{50}$	2.38±0.14b	7.55±0.2b	0.22±0.02c	0.99±0.14b
$IF_{25}PM_{75}$	2.58±0.03ab	10.87±0.7a	0.32±0.01a	0.91±0.06b
IF_0PM_{100}	2.08±0.09cd	5.72±0.9c	0.21±0.01c	0.56±0.08c
CV%	5.28	8.03	5.20	18.47
$LSD_{0.05}$	0.22**	1.09**	0.02**	0.28**

IF= Inorganic fertilizers; PM=Poultry manure; NS= not significant. Means within the same column followed by the different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD. LSD= Least significant difference; CV= Coefficient of variance.

4.2.2.1.2 P concentration and uptake

Different combinations of IF and PM significantly influenced the P concentration and its uptake by *A. vera* leaf (Table 4.5). The highest concentration (0.34%) was obtained from $IF_{100}PM_0$ which was statistically identical with the P concentration of the leaves of *A. vera* plant fertilized with $IF_{25}PM_{75}$ but significantly different from other treatments. The lowest P concentration (0.13%) was obtained from the plants receiving no fertilizer.

P uptake varied from 0.21-1.43 g plant^{-1}. The uptake of P was highest when the plant was treated with $IF_{100}PM_0$ which was identical with $IF_{25}PM_{75}$. This may be due to the highest leaf P concentration and dry leaf weight harvested from these treatments as nutrient uptake was calculated from their concentrations and corresponding dry leaf weight. The lowest P uptake as expected was observed in the control treatment. The interaction between organic and conventional farming showed an increasing effect on phosphorus uptake by potato tuber and haulm (Islam and Nahar, 2012). The present study coincided with the findings of Islam and Munda (2012), Manoj *et al.* (2012) who reported highest uptake of N, P and K with the application of inorganic and organic fertilizers. Ghosh *et al.* (2014) and Azam *et al.* (2013) support the results of the study that the integration of organic fertilizers along with synthetic fertilizers results into highest P uptake by plants. Brahmachari and Mandal (2000) reported maximum NPK uptake by rice under FYM + NPK treatment compared to control.

4.2.2.1.3 K concentration and uptake

Potassium concentration and uptake by *A. vera* leaf were significantly affected by different treatments of IF and PM (Table 4.6). The highest K concentration (1.88%) was obtained from $IF_{100}PM_0$ which was statistically identical with the K concentration of the leaves of *A. vera* plant fertilized with $IF_{75}PM_{25}$ but significantly different from other treatments. The minimum K concentration was recorded in case of no fertilizer treatment.

The maximum K (7.81 g plant^{-1}) uptake by *A. vera* was recorded in IF treated plants only and the minimum (1.7 g plant^{-1}) recorded in case of control (IF_0PM_0). The second highest K concentration (6.18 g plant^{-1}) was obtained from $IF_{75}PM_{25}$ treated plants which was identical with others such as $IF_{50}PM_{50}$ and $IF_{25}PM_{75}$. Sreelatha *et al.* (2006) and Ghosh *et al.* (2014) showed that combined use of organic and mineral fertilizers significantly increased the plant potassium uptake.

Table 4.6 Integrated effects of IF and PM on K and S concentrations and their uptake by *A. vera*

IF and PM levels	Potassium		Sulphur	
	Concentration (%)	Uptake (g $plant^{-1}$)	Concentration (%)	Uptake (g $plant^{-1}$)
IF_0PM_0	1.02±0.06e	1.7±0.18e	0.17±0.01c	0.4±0.29e
$IF_{100}PM_0$	1.88±0.09a	7.81±1.09a	0.24±0.01a	1.88±0.98a
$IF_{75}PM_{25}$	1.82±0.07a	6.18±0.76bc	0.22±0.01ab	1.53±0.77bc
$IF_{50}PM_{50}$	1.61±0.06b	5.13±0.52c	0.23±0.04ab	1.39±0.74c
$IF_{25}PM_{75}$	1.48±0.09c	6.21±0.18b	0.22±0.01ab	1.84±0.91ab
IF_0PM_{100}	1.17±0.05d	3.20±0.28d	0.19±0.02bc	0.92±0.54d
CV%	4.80	11.94	9.11	13.09
LSD	0.13**	1.07**	0.03*	0.16**

IF= Inorganic fertilizers; PM=Poultry manure; NS= not significant. Means within the same column followed by the different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD; LSD= Least significant difference; CV= Coefficient of variance.

Sheoran *et al.* (2015) also observed that combined application of N based mineral fertilizers and vermicompost had significant effect on K uptake. Jeegedeeswari *et al.* (2000) reported that K uptake in rice plant was higher in urban compost treated plot over green manure and controlled treatment.

4.2.2.1.4 S concentration and uptake

Different combinations of IF and PM brought a significant influence on the S concentration and uptake by *A. vera* leaf (Table 4.6). The highest S concentration (0.24%) was obtained from the treatment $IF_{100}PM_0$ which was statistically identical with the S concentrations of the leaves of *A. vera* plant fertilized with all other treatments except sole application of PM. The lowest S concentration was obtained from the plants receiving no S fertilizer.

S uptake varied from 0.4-1.88 g $plant^{-1}$. The uptake of S as expected was maximum in 100% IF followed by 75% PM and 25% IF. The lowest S uptake was observed in the control treatment. Increased uptake of NPK and S by tomato plant was observed by Olasantan (1991) applying poultry litter.

4.2.2.1.5 Ca concentration and uptake

Concentration and uptake of Ca by *A. vera* showed a significant variation for treatment combinations of IF and PM (Table 4.7). The highest Ca concentration (0.25%) was recorded in 100% poultry manure treated plant and the lowest (0.13%) was recorded in case of zero fertilizer treatment which was statistically similar with plants treated with 100% IF and 75% of IF with or without PM.

The Ca uptake by *A. vera* ranged from 0.21-1.03 g plant^{-1}. Maximum uptake was noticed as expexted in 75% PM treated plants which was statistically dissimilar with other treatments. Ca uptake of other treatment combinations except control was statistically identical. The results of our study was supported by the findings of Blum *et al.* (2003) who reported that Ca uptake by squash fruit was significantly enhanced with the addition of farm yard manure.

Table 4.7 Integrated effects of IF and PM on Ca and Mg concentrations and their uptake by *A. vera*

IF and PM levels	Calcium		Magnesium	
	Concentration (%)	Uptake (g plant^{-1})	Concentration (%)	Uptake (g plant^{-1})
IF_0PM_0	0.13±0.02d	0.21±0.03c	0.22±0.0.1b	0.36±0.02d
$IF_{100}PM_0$	0.19±0.01d	0.78±0.18b	0.24±0.03b	1.01±0.15c
$IF_{75}PM_{25}$	0.14±0.03cd	0.47±0.09b	0.29±0.03b	0.98±0.17c
$IF_{50}PM_{50}$	0.22±0.04bc	0.71±0.06b	0.32±0.02b	1.03±0.11c
$IF_{25}PM_{75}$	0.25±0.03a	1.03±0.05a	0.36±0.02a	1.50±0.14a
IF_0PM_{100}	0.17±0.01b	0.48±0.11b	0.41±0.04a	1.14±0.24b
CV%	12	16	8.83	15
$LSD_{0.05}$	0.04**	0.17**	0.05**	0.27**

IF= Inorganic fertilizers; PM=Poultry manure; NS= not significant; LSD= Least significant difference; CV= Coefficient of variance. Means within the same column followed by the different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD.

4.2.2.1.6 Mg concentration and uptake

The results presented in Table 4.7 indicate that there were significant variation in Mg concentration and uptake by *A. vera* due to the effect of various treatments. The highest Mg concentration (0.41%) was determined from 75% PM treated plant which was statistically similar with sole application of PM and dissimilar with others. The second height Mg concentration was from 100, 75 and 50% of IF treated plants with or without PM. The lowest concentration (0.21 %) was obtained from control.

Magnesium uptake by *A. vera* was in the range from 0.36 to 1.5 g plant^{-1}. Maximum Mg uptake (1.5 g plant^{-1}) by *A. vera* was found where 75% poultry manure and 25% IF was used followed by 100% PM treated plant. The lowest uptake was calculated from no fertilizer treated plant. The result of the present study was congruented with the results of Islam and Nahar (2012) in potato due to the application of poultry manure and Ghosh *et al.* (2014) in NERICA 10 due to the combined application of IF and cowdung.

4.2.2.1.7 Fe concentration and uptake

Different treatment combinations of IF and PM significantly differentiate the concentration and uptake of Fe by *A. vera*. The concentration ranged from 119 to 331 µg g^{-1} due to different treatments effect. The highest Fe concentration (331 µg g^{-1}) was recorded in the 100% PM treated plant which was statistically different from other treatments. Lowest Fe concentration (55.81 µg g^{-1}) was found where no fertilizer was used.

Maximum Fe uptake (105 mg plant^{-1}) was observed in 75% PM and 25% IF treated plant which was statistically dissimilar to all other treatments. The second highest Fe uptake (89 mg plant^{-1}) was found in the sole application of PM. The lowest Fe uptake (20 mg plant^{-1}) was found in the control. Iron concentrations were gradually increased with the increased percentages of PM though uptake did not follow the same trend. Prasad *et al*. (1984) reported that addition of poultry manure alone or in combination with N, P, K, Zn and Fe increased the uptake of Zn and Fe by wheat and rice. Faiyard *et al*. (1991) recorded an increase in N, P, K, Fe, Mn and Cu concentrations in faba bean**s** due to the application of poultry manure in comparison with FYM. Higher uptake of nutrients with the application of organic fertilizer might be due to higher nutrient concentration along with higher biomass production (Swarup and Yaduvanshi, 2006 and Banik *et al*., 2006). Application of organic manure along with chemical fertilizer accelerates the microbial activity (Rani and Srivastava, 1997), increases nutrients use efficiency (Narwal and Chaudhary, 2006) and enhances the availability of the native nutrients to the plants resulting higher uptake of nutrients (Bhandari *et al*., 1992).

4.2.2.1.8 Zn concentration and uptake

Zinc concentration of *A. vera* leaf was not significantly affected by different combinations of IF and PM though the uptake was significant (Table 4.8). It might be due to the fact that dry weight of *A. vera* leaf of the treatments was significantly different.However, the highest Zn concentration (80 µg g^{-1}) was obtained from IF_0PM_{100} and the lowest from the plants receiving no fertilizer.

The highest Zn uptake (34 mg $plant^{-1}$) was found in 75% of PM along with 25% of IF which was identical with the 100% IF treated plant and the lowest uptake of 12 mg $plant^{-1}$ was observed in control treatment. Ayeni *et al.* (2008) showed that poultry manure increased the uptake of N, P, K, Ca, Mg, Zn, Fe and Cu by maize grain. This is consistent with the present study that poultry litter enhanced nutrient uptake of *A. vera* in addition to increasing nutrient status in soil. Kumar and Chopra (2013) also reported higher contents of Fe, Mn and Zn in French bean (*Phaseolus vulgaris* L.) amended with sewage sludge.

4.2.2.1.9 Mn concentration and uptake

Integrated levels of IF and PM brought a significant variation on the Mn concentration and uptake by *A. vera* leaf (Table 4.8). The highest Mn concentration (223 µg g^{-1}) was obtained from the 100% PM treatment which was statistically identical with the Mn concentration of the leaves of *A. vera* plant fertilized with 75% PM along with 25% IF. The lowest Mn concentration (67 µg g^{-1}) was obtained from the plants receiving no fertilizer.

Mn uptake varied from 11-82 mg $plant^{-1}$ across the treatments. The uptake of Mn was maximum in 75% PM plus 25% IF treated plant followed by 100% IF which was identical with 100% PM and 75% IF plus 25% PM. The lowest Mn uptake was observed in the control treatment. Swarup (1984) and Chaudhary and Narwal (2005) reported that the incorporation of manures brought about a remarkable improvement in the availability of native and applied micronutrient cations (Zn, Fe and Mn) in soil. Abdalla *et al.* (2007) also reported significantly higher contents of Fe, Zn, Mn and Co except Cu in forage due to the application of poultry manure.

Table 4.8 Integrated effects of IF and PM on Fe, Zn and Mn concentrations and their uptake by *A. vera*

IF and PM levels	Iron		Zinc		Manganese	
	Concentration ($\mu g\ g^{-1}$)	Uptake (mg plant $^{-1}$)	Concentration ($\mu g\ g^{-1}$)	Uptake (mg plant $^{-1}$)	Concentration ($\mu g\ g^{-1}$)	Uptake (mg plant $^{-1}$)
IF_0PM_0	119±6.79e	20±1.22e	73±3.24	12±1.6d	67±2d	11.14±1.2d
$IF_{100}PM_0$	139±5.93d	58±7.96cd	75±2.67	31±3.1a	84±2.5c	34.89±2.9b
$IF_{75}PM_{25}$	154±7.18d	53±6.58d	77±2.82	26±1.4b	113±1.5bc	38.25±3.7bc
$IF_{50}PM_{50}$	213±4.83c	68 ±5.11c	77±5.19	25±1.8bc	132±2.1b	42.09±4.0c
$IF_{25}PM_{75}$	250±11.62b	105±2.95a	79±8.56	34±0.7a	194±4.6a	81.61±5.2a
IF_0PM_{100}	331±13.01a	89±8.58b	80±2.69	22±3.2c	223±3.5a	60.95±6.6bc
CV%	4.27	9.17	6.93	8.74	2.14	9.52
$LSD_{0.05}$	17**	10.7**	NS	3.7**	5.2**	7.59**

IF= Inorganic fertilizers; PM=Poultry manure; NS= not significant, LSD= Least significant difference; CV= Coefficient of variance. Means within the same column followed by the different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD.

4.2.2.2 Protein content

Protein which would be serving as enzymatic catalyst, mediate cell responses, control growth and cell differentiation (Whimey and Rolfes 2005) is considered as the third highest (10.50 %) parameter *A. vera* (Haque *et al.*, 2014). The result reveals that the protein content of *A. vera* gel was significantly influenced by different combinations of IF and PM (Fig. 4.8 and Appx. 5). Maximum protein content (15.85%) was observed in $IF_{100}PM_0$ treated plant and minimum content (10.94%) was found in control. On the other hand, the plants treated with $IF_{100}PM_0$ and $IF_{25}PM_{75}$ biosynthesized statistically identical percent of protein. $IF_{25}PM_{75}$ and $IF_{50}PM_{50}$ treated plants also showed identical protein content. These results are in accordance with the findings of a study (Femenia *et al.*, 1999). They reported 7.56-15.4% crude proteins on compositional features of *A. vera* tissues. Saleha (1992) observed an increase in the total carbohydrate, protein and ascorbic acid and a decrease in the crude fiber content of okra due to the application of 10 kg N as ammonium sulphate + 50 kg N as poultry manure.

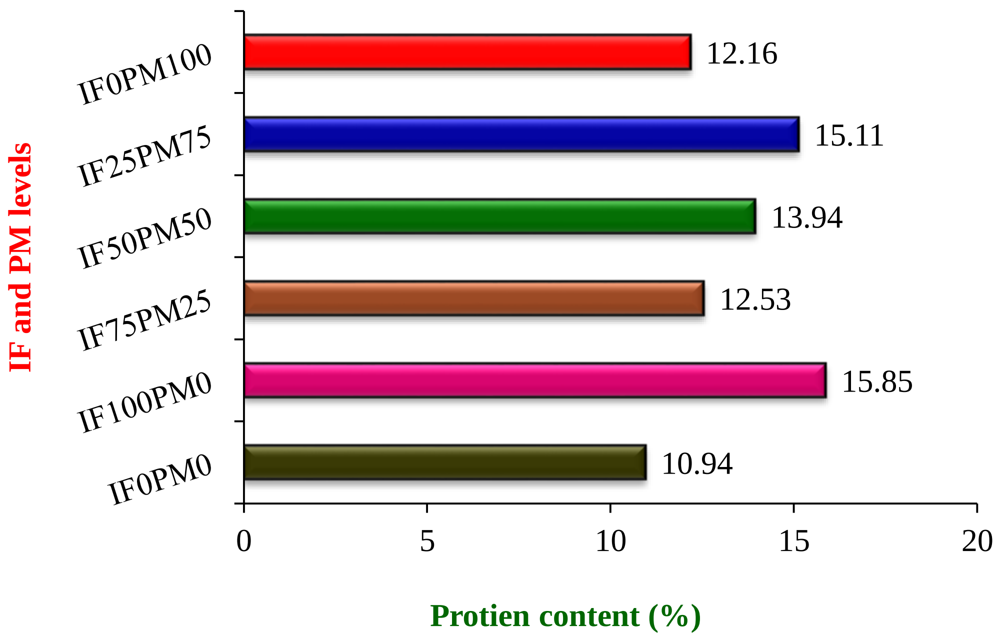


Fig.4.8 Effects of IF and PM on the protein content of *A. vera*

4.2.2.3 Chlorophyll concentrations

The combined application of IF and PM had significant effect on the chlorophyll concentrations but the trend and peaks were different than their individual applications. This may be due to the complimentary affect of IF and PM resulting in better nutrient availability. Different manuring treatment also significantly affected the chlorophyll concentration of *A. vera* in this study (Table 4.9). The highest chlorophyll a (0.29 mg g^{-1} FW) and chlorophyll b (0.116 mg g^{-1} FW) concentrations at harvest were observed in the treatment where 25% IF along with 75% PM was applied which was statistically superior to other treatments. The second highest chlorophyll a and chlorophyll b concentrations were observed in the plants treated with 100% PM followed by application of 50% PM with or without IF. The lowest chlorophyll a and chlorophyll b were observed in control pot where no IF and PM was applied (Table 4.9). An increased trend of both chlorophyll a and chlorophyll b was observed with the increased levels of PM. It could be due to the beneficial effect of organic matter in soil properties and plant growth (Dexter, 1988; Tisdall and Oades, 1982; Uyanoz *et al.*, 2002).

4.2.2.4 Pharmaceutical compounds

4.2.2.4.1 Aloin concentration

A. vera has different secondary metabolites and the most important of them is Aloin. Aloin is the active components that has anti-ulcer, inhibiting action against some bacteria and fungi-inflammation, healing ability of skin burns and cutaneous injuries properties. As shown in Table 4.9, integrated application of IF and PM significantly increased aloin concentration of *A. vera* leaf.

Table 4.9 Integrated effects of IF and PM on aloin, chlorophyll, total phenolic and total flavonoid concentrations of *A. vera*

IF and PM levels	Aloin ($\mu g\ g^{-1}$ FW)	Chlorophyll ($mg\ g^{-1}$ FW)		TFC (mg QE 100 g^{-1} FW)	TPC (mg GAE g^{-1} FW)
		"A''	"B"		
IF_0PM_0	345.7±9.7 e	0.19±0.0053 c	0.068±0.005 c	5.68±0.32 e	15.63±0.53 d
$IF_{100}PM_0$	388.8±14.9 d	0.26±0.109 ab	0.095±0.007 b	9.58±0.53 d	20.98±0.98 c
$IF_{75}PM_{25}$	415.6±10.5 c	0.23±0.0087 bc	0.091±0.002 b	12.28±1.45 c	22.57±0.69 bc
$IF_{50}PM_{50}$	456.9±9.5 b	0.25±0.0034 ab	0.093±0.004 b	16.35±0.61 b	27.9±1.11 a
$IF_{25}PM_{75}$	467.8±11.7 b	0.29±0.0086 a	0.116±0.005 a	19.61±1.04 a	29.08±1.20 a
IF_0PM_{100}	492.4±14.0 a	0.287±0.0034 a	0.100±0.002 b	15.89±0.24 b	24.54±2.21 b
CV	2.79	11.47	9.47	6.17	5.30
$LSD_{0.05}$	21.2**	0.05*	0.02**	1.45**	2.21**

IF = Inorganic fertilizers; PM = Poultry manure; NS = Not significant; TFC = Total flavonoid concentration, TPC = Total phenolic concentration; QE = Quercetin equivalent; GAE = Gallic acid equivalent; FW = fresh weight; LSD= Least significant difference; CV= Coefficient of variance. Means within the same column followed by the different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD.

Maximum aloin concentration (492.4 $\mu g\ g^{-1}$) was biosynthesized in the plants treated with IF_0PM_{100} which was identically followed by the amounts of leaf aloin of the plants having the treatments $IF_{25}PM_{75}$ (467.8 $\mu g\ g^{-1}$) and $IF_{50}PM_{50}$ (456.9 $\mu g\ g^{-1}$). Aloin concentration of leaf increased about 42.44% over control. Previous report (Saha *et al.,* 2005) confirmed that application of PM along with IF significantly increased aloin concentration of *A. vera* leaf. The result of the present study was in harmony with those obtained by Shadia (1996) in *A. vera* plant. PM contains higher amount of plant nutrients at the same time it regulates the physiochemical environment of soil ecosystem. The amount of aloin was enhanced in *A. vera* with the increasing rate of nitrogen (Ji-Dong *et al.*, 2006).

4.2.2.4.2 Total phenolic and flavonoid concentrations

Phenolic compounds are a class of antioxidant agents which act as free radical scavengers and are responsible for antioxidant activity in medicinal plants (Shahidi and Wanasundara, 1992). Free radical may cause many disease conditions such as cancer and coronary heart disease in human (Javanmardi *et al.*, 2003; Löliger, 1991). Many plants extracts containing bioactive compounds including phenolics and flavonoid exhibit efficient antioxidant properties and prevent from free radical damage (Larson, 1998; Koleva *et al.*, 2002). Due to above mentioned reasons total phenolic and flavonoid concentration in *A. vera* at different doses of fertilization have been determined.

Data for phenolic compounds and flavonoids concentration in different IF and PM treated plants are presented in Table 4.9. Integrated application of IF and PM at different combinations significantly influenced the phenolic and flavonoids concentration of *A. vera* gel. Highest phenolic concentration (29.08 mg g^{-1}) was found in $IF_{25}PM_{75}$ treated plants which were identically followed by 50% IF and PM treated plants. Lowest phenolic concentration (24.54 mg g^{-1}) was obtained from control treatment. The highest amount of flavonoids concentration (19.61 mg 100 g^{-1}) was observed in $IF_{50}PM_{50}$ treatment and the lowest (5.68 mg 100 g^{-1}) in the control. These results are in agreement with those reported by Javanmardi *et al.* (2003) in *Ocimum basilicum* and Zheng (2001) in selected herbs. Yavari *et al.* (2013) reported that application of vermicompot increase total phenolic and flavonoid concentrations at 30% and 15% vermicompost, respectively. Another study (Saradhi *et al.*, 2007) reported that applcation of PM along with IF increased the phenolic compounds in latex of *A. vera* leaves. Increasing nutrient elements in the soil treated with PM led to more secondary metabolites synthesis. The increase in phenolic concentration is related to the balance between carbohydrate sources and sinks. Thus, when there are more carbohydrates, there are also more phenolic compounds. However, excessive use of IF and PM increases a substrate's imbalance which has inhibitory effect on plant's activity. This can reduce the amount of phenolic compounds in high percentages of comibination of IF and PM.

4.2.2.5 Correlation studies among different parameters of *A. vera*

Correlation studies give the amount of association between any pair of parameter. The direct and indirect effects of the parameters of yield are however, can not be revealed by this study. Especially, when more parameters are included in the study, the indirect contribution becomes more complex and paramixing. However coefficient analysis helps in partitioning the correlation coefficient into direct and indirect effects, thereby providing relative importance of each parameter.

4.2.2.5.1 Correlation among different physical parameters of *A. vera*

Correlation coefficient analysis helps to determine the nature and degree of relationship between different growth parameters and yield. Statistical relationship of plant height, leaf number and fresh leaf weight with fresh gel weight has been found out. The correlation and regression lines of these have been shown in Fig. 4.9. The results show that the concerned physical parameters were significantly and positively correlated with fresh gel weight where correlation coefficients (r) were 0.763*, 0.809* and 0.940**, respectively. The relationships were more evident from the regression lines ($y = 73.63x - 1418$, $y = 190.9x - 857.1$ and $y = 0.679x - 521.9$, respectively) where increase of concerned parameters increased fresh gel weight significantly. Ramabai *et al.* (1992) observed significant and positive association between grain yield per plant and number of productive tillers per hill, plant height, panicle length and number of grains per panicle both at genotypes and phenotypic levels.

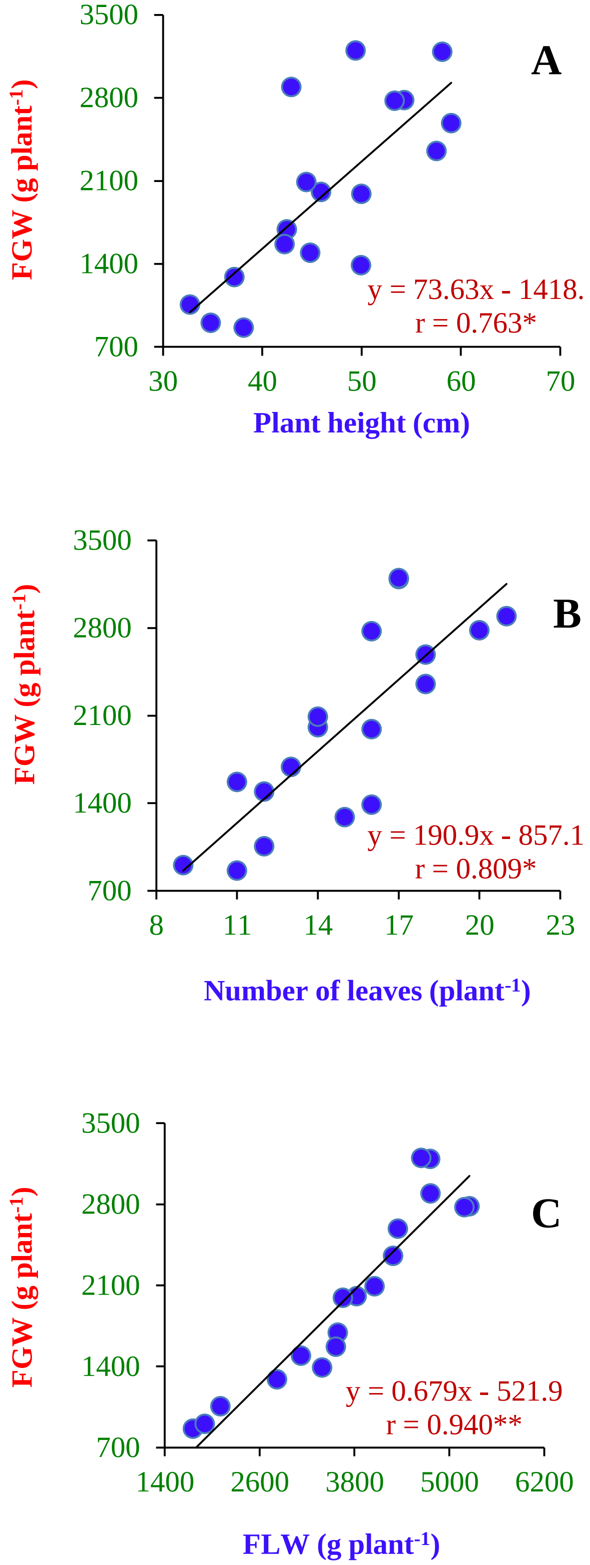
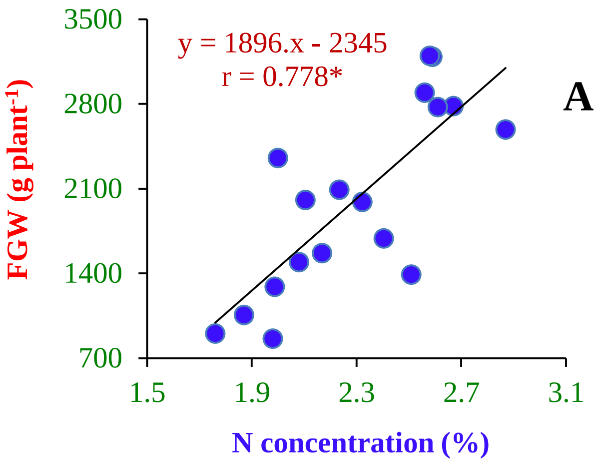
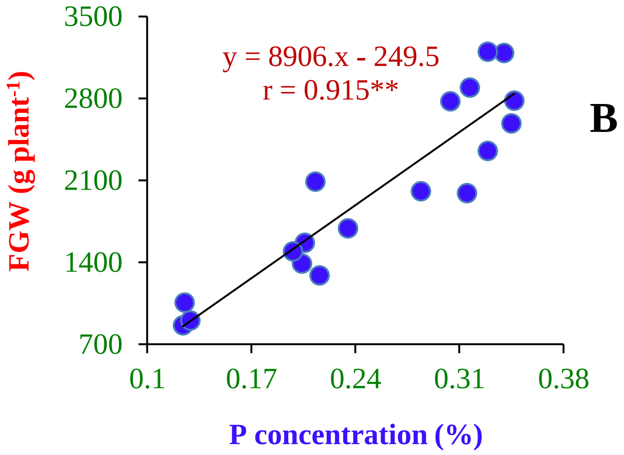


Fig. 4.9 Relationships between (A) plant height and FGW (B) number of leaves and FGW (C) FLW and FGW of *A. vera* as influenced by IF and PM. FLW = Fresh leaf weight, FGW = Fresh gel weight (n = 18).

4.2.2.5.2 Correlation between fresh gel weight (FGW) and mineral nutrient concentrations

Statistical relationships among FGW and plant mineral nutrient concentrations have been studied. The correlation matrix and regression lines of these are shown in Fig. 4.10. There were strong and positive relationship between FGW and mineral concentrations like N, P, K which had been confirmed with correlation coefficients (r) 0.778*, 0.915** and 0.771*, respectively. The relationships were more evident from the regression lines y = 1896.x – 2345, y = 8906.x – 249.5 and y = 1668.x – 491.8, respectively. The positive slopes indicate that increase in N, P and K concentrations result an increase in fresh gel weight of *A. vera*. The positive relationship N, P and K concentrations with FGW attributed to the roles of N, P and K as macronutrients in plant nutrition. Nitrogen is known to play a significant role in plant photosynthetic activity thereby resulting in increase in leaf length and width, and number of leaves (Acquaah, 2006). Phosphorus and K on the other hand, play a functional role in formation of more roots thereby, enhancing uptake of nutrients. This fact has been reported by Majanbu *et al.*, (1986) in their studies of crop response to N and P fertilizer application. The positive interaction of nutrients on fresh weight of *A. vera* was an indication of the importance of the nutrient elements in plant nutrition. It is also a measure of inter dependency between the parameters evaluated (Egbuchua & Enujeke, 2015).





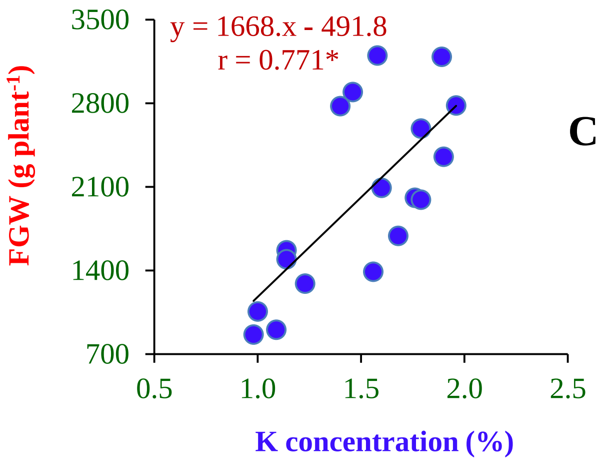


Fig. 4.10 Relationships between (A) N concentration and FGW (B) P concentration and FGW (C) K concentration and FGW of *A. vera* as influenced by IF and PM. FGW = Fresh gel weight (n = 18).

4.2.2.5.3 Correlation among mineral nutrient concentrations of *A. vera*

Interaction between nutrients in crop plants occurs when the supply of one nutrient affects the absorption and utilization of other nutrients. Nutrient interactions within the plants are among ions whose chemical properties are suficiently similar that they compete for site of adsorption, absorption, transport, and function on plant root surfaces or within plant tissues. Hiatt and Leggett (1974) suggested that cation-cation and anion-anion interactions occur mostly at the membrane level and are primarily of a competitive nature. Cation-anion interactions occur at both the membrane and in cellular processes after absorption. These cellular interactions are less understood. Generally an excess of one cation in the nutrient medium reduces the net uptake of other cations, whereas the sum of cations in the plant tissue often remains nearly constant.

There was a direct significant and positive relationship between N and P concentrations of *A. vera* having the correlation coefficient of r = 0.751* (Fig. 4.11). The relationships were more evident from the regression line y = 0.187x – 0.177, y = 8906.x – 249.5 and y = 1668.x – 491.8, respectively. Phosphorus and potassium concentrations showed significant positive correlation with S at 5% level of probability (Fig. 4.11). The values of correlation coefficient (r) were 0.71* and 0.81* with the regression lines y = 2.043x - 0.182 and y = 9.654x - 0.562, respectively. The K and P also showed significant correlation having r value 0.848* with each other which was confirmed by the regression line y = 3.516x + 0.606 (Fig. 4.11). There were significant relations between Mg with Mn and Fe at 5% level of probability. The values of correlation coefficient, r = 0.849* and 0.937** with the regression lines y = 0.000x + 0.034 and y = 0.000x + 0.124, respectively. The positive interaction of nutrients on fresh weight of *Aloe vera* was an indication of the importance of the nutrient elements in plant nutrition. It is also a measure of inter dependency between the parameters evaluated. These findings are consistent with earlier findings of Mankar and Satao (1995), Ray *et al*. (2003), Babaji *et al.* (2006), Egbuchua & Enujeke (2015) and Abdulsalam and Ogunsola (2006) in the their studies of crop production.

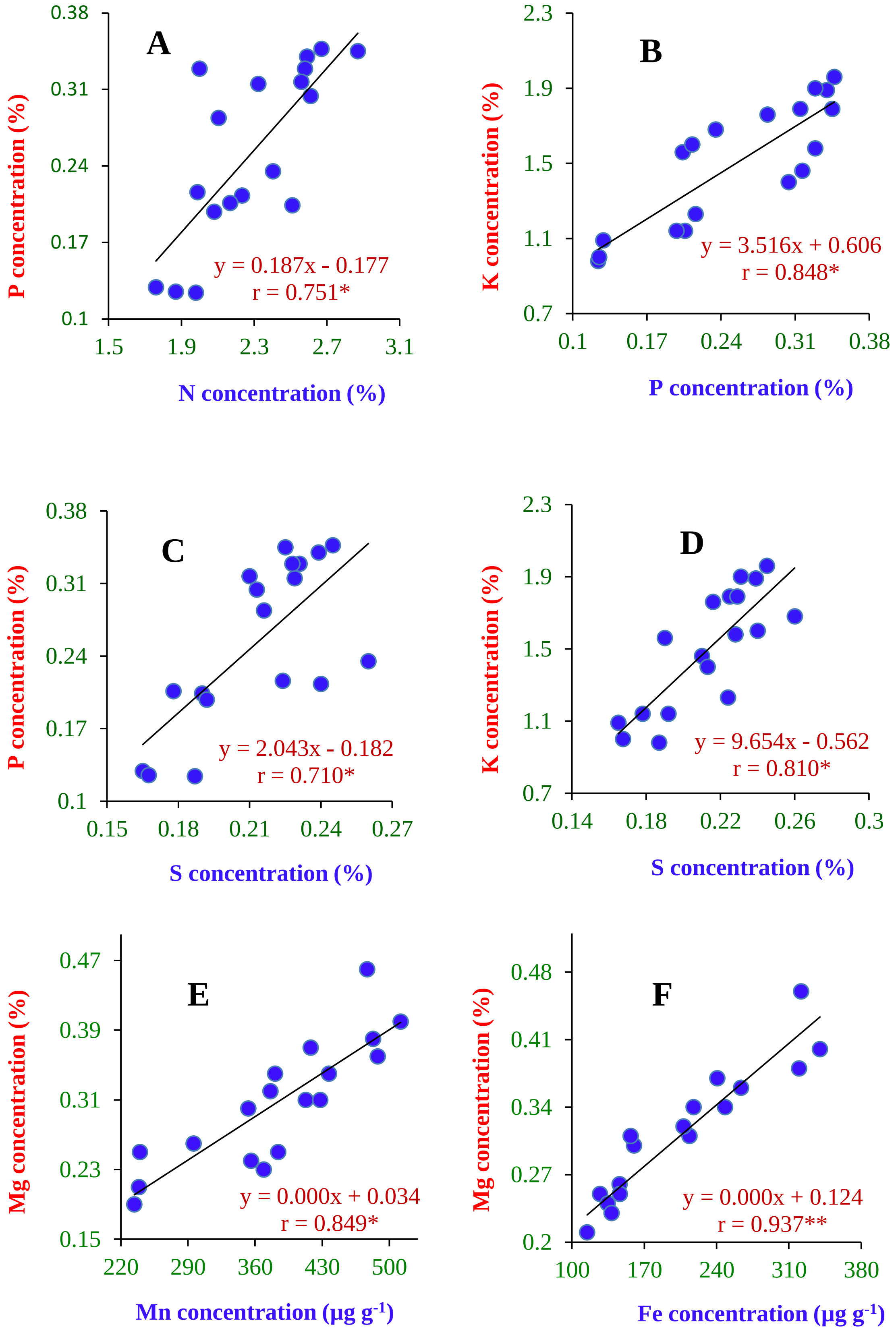


Fig. 4.11 Relationships between (A) N and P concentrations (B) P and K concentrations (C) P and S concentrations (D) S and K concentrations (E) Mg and Mn concentrations (F) Mg and Fe concentrations of *A. vera* as influenced by IF and PM (n = 18).

4.2.2.5.4 Correlation between pharmaceutical compounds

It is shown from Fig. 4.12 that were strong significant and positive relationships between the concerned pharmaceutical compounds of *A. vera*. The correlation coefficients (r = 0.981**, 0.946** and 0.935**) were found out significant at 1% level of probability. The positive slopes indicates that pharmaceutical compounds directly correlated with each other i.e. increase in one compound result in an increase in other compund.

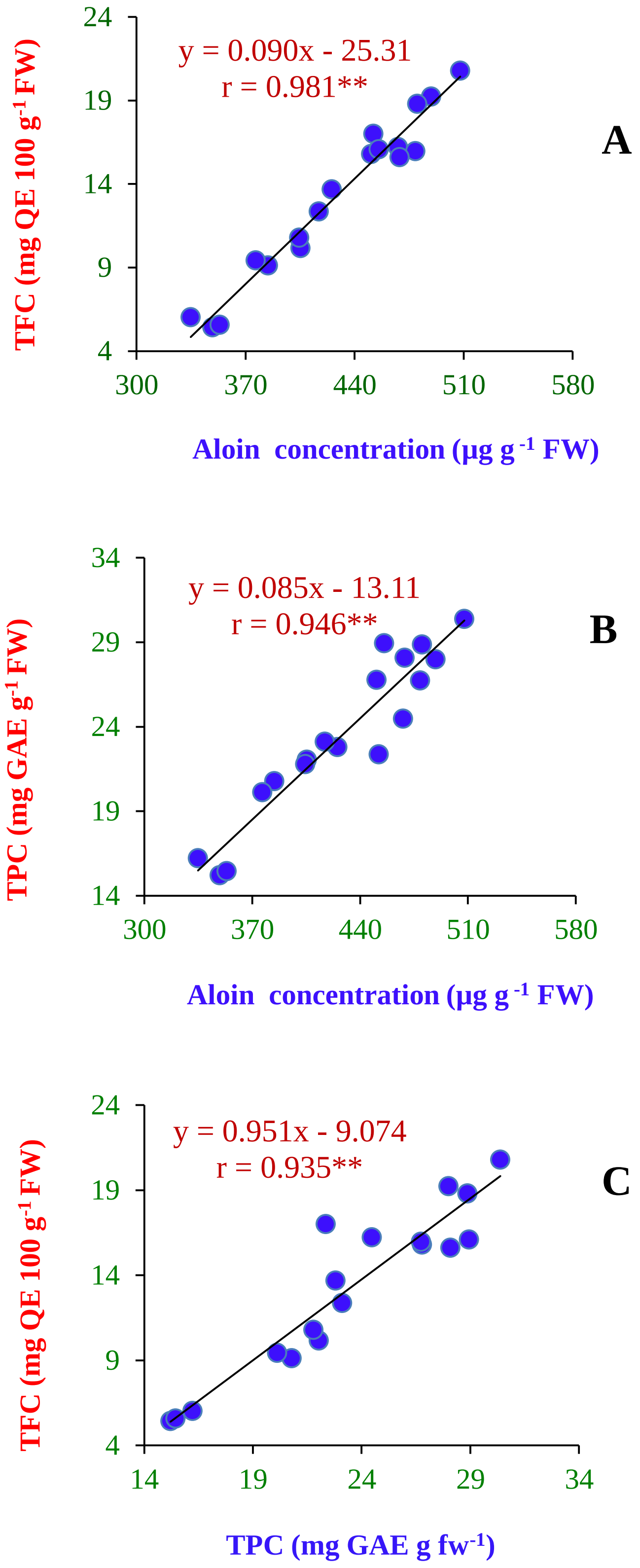


Fig. 4.12 Relationships between (A) Aloin and TPC (B) Aloin and TFC (C) TPC and TFC of *A. vera* as influenced by IF and PM. TPC = Total phenolic concentration, TFC = Total flavonoid concentration, fw = fresh weight (n = 18).

4.2.2.5.5 Correlation between pharmaceutical compounds and mineral concentrations

The results presented in Fig. 4.13a, 4.13b and 4.13c show that there were significant and positive correlations between Mg, Fe and Mn concentrations with the pharmaceutical compounds of *A. vera* leaves. The correlation coefficients (r) are 0.902**, 0.918**, 0.920**, 0.918**, 0.921**, 0.906**, 0.885*, 0.896* and 0.919**, respectively. The regression equations ($y = 655.1x + 226.9$, $y = 0.646x + 298.0$, $y = 0.836x + 314.5$, $y = 60.53x - 5.331$, $y = 0.059x + 1.272$, $y = 0.075x + 2.994$, $y = 57.99x + 5.667$, $y = 0.056x + 12.01$ and $y = 0.075x + 13.23$, respectively) are showing gradual increase in pharmaceutical compounds (i.e. aloin, total phenolic and flavonoid concentrations) with increasing Mg, Fe and Mn concentrations of *A. vera* leaf.

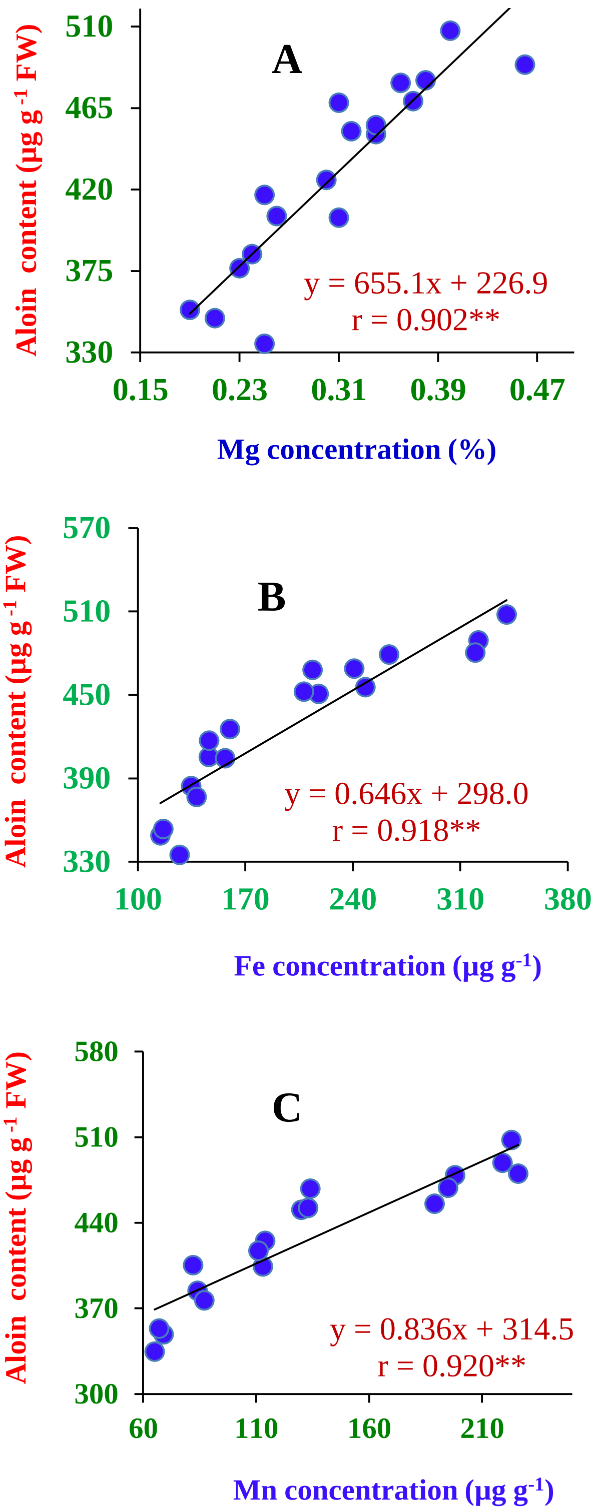


Fig. 4.13a Relationships between (A) Mg and Aloin concentrations (B) Fe and Aloin concentrations (C) Mn and Aloin concentrations of *A. vera* as influenced by IF and PM. TPC = Total phenolic concentration, TFC = Total flavonoid concentration (n = 18).

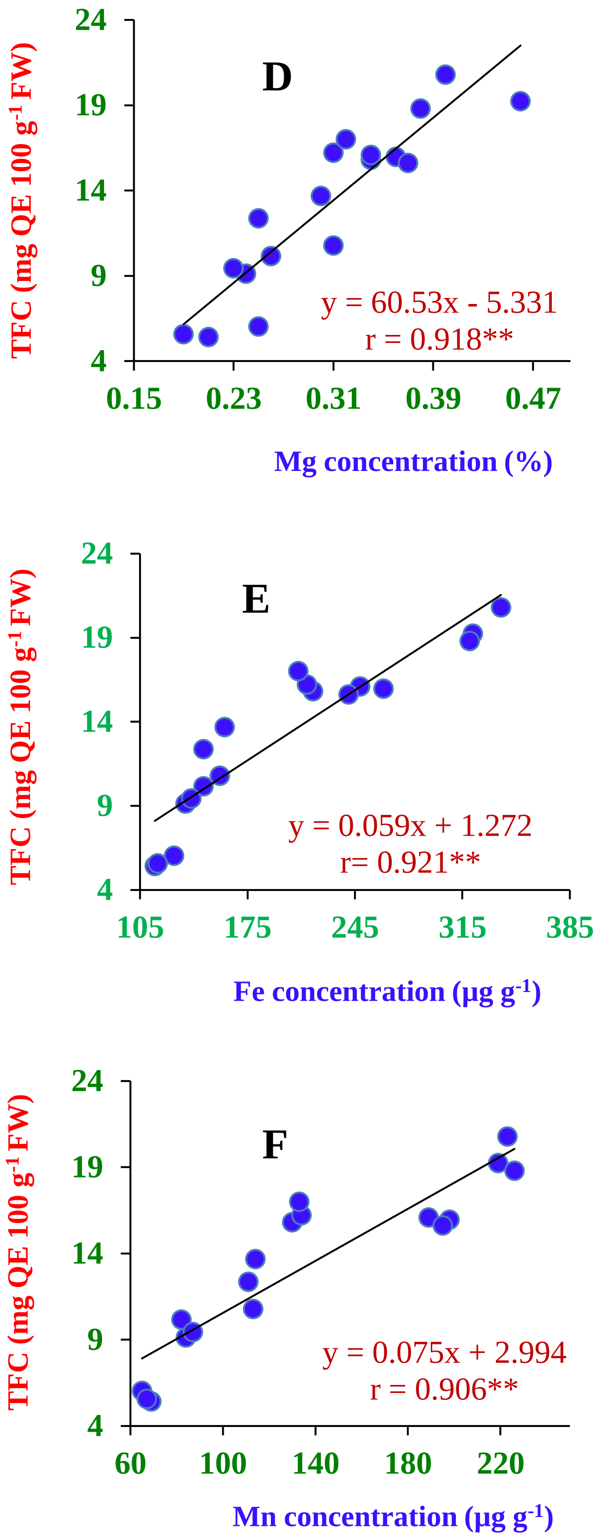


Fig. 4.13b Relationships between (D) Mg concentration and TFC (E) Fe concentration and TFC (F) Mn concentration and TFC of *A. vera* as influenced by IF and PM. TPC = Total phenolic concentration, TFC = Total flavonoid concentration (n = 18).

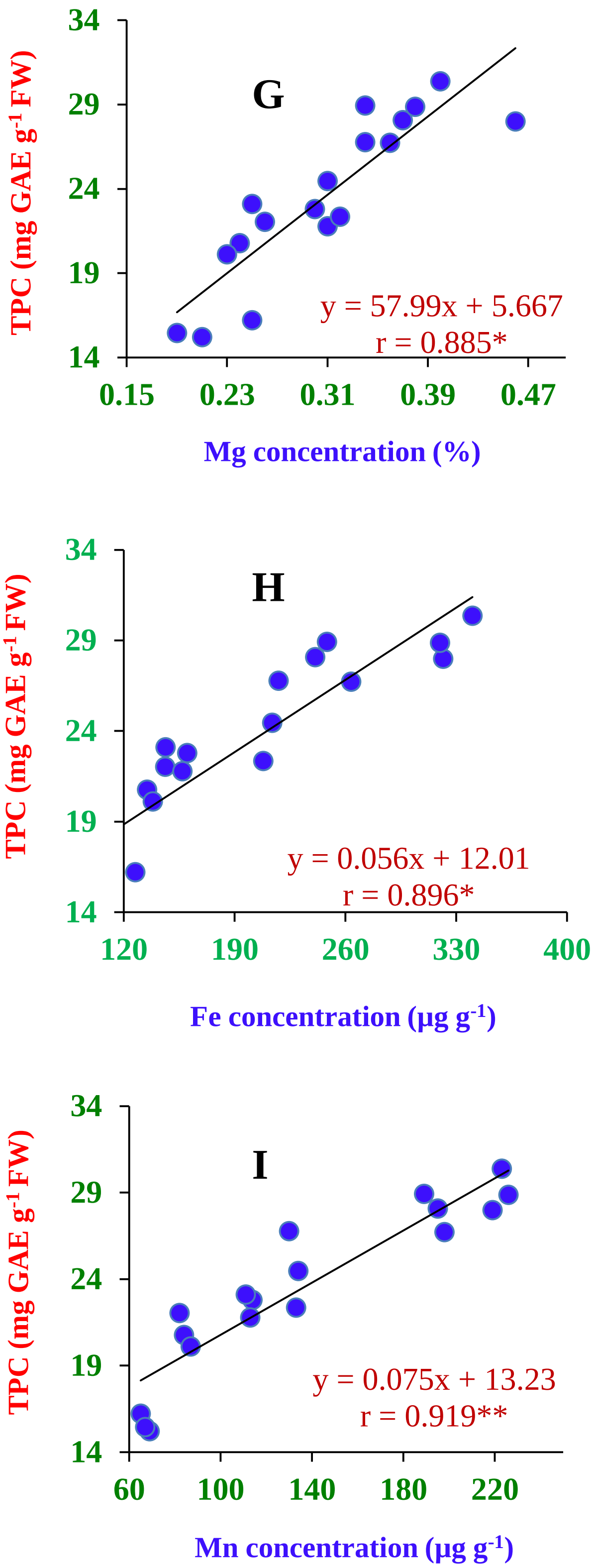


Fig. 4.13c Relationships between (G) Mg concentration and TPC (H) Fe concentration and TPC (I) Mn concentration and TPC of *A. vera* as influenced by IF and PM. TPC = Total phenolic concentration, TFC = Total flavonoid concentration (n = 18).

4.2.3 Integrated effects of IF and PM on post-harvest soil fertility

Application of IF and PM significantly influenced the post harvest properties of the soil (Table 4.10a and 4.10b). The data reveal that the pH of the soil ranged from 5.1 to 6.3 when PM was applied with or without IF. The acidity of the soil was reduced to some extent and favors the growth and yield of *A. vera*. Wang *et al.* (2013) are of the same opinion that any organic material if added to the soil that will reduce soil acidity. They reported that addition of the plant residues increased soil pH by 0.2 – 1.2 U. This might be due to the fact that when organic residues (plant or animal) were added to the soil, they released organic anions which neutralized the hydrogen ion of the acid soil.

Organic matter content ranged from 1.56 to 2.50%. This increasing OM content of the soil might be due to the additions of poultry manure. The contents of total N, available P, exchangeable K, Ca, Mg, available S, Zn and B were significantly increased with the increased levels of PM. However, the highest values of all the parameters were obtained from sole application of PM and the lowest from the initial soil (IF_0PM_0) as the nutrients released rapidly and consistently from this manure over the growth period of *A. vera*.

Table 4.10a Integrated effects of IF and PM on the fertility of post harvest soils

IF and PM levels	pH	Organic matter (%)	Total N (µg g^{-1})	Available P (µg g^{-1})	Exch. K (C mol kg^{-1})
IF_0PM_0	5.16±0.2d	1.56±0.3d	0.07±0.0e	3.04±0.2f	0.19±0.05c
$IF_{100}PM_0$	5.17±0.1cd	1.62±0.1c	0.10±0.0d	4.64±0.1e	0.22±0.03c
$IF_{75}PM_{25}$	5.23±0.4c	1.94±0.1b	0.21±0.0c	6.21±0.3d	0.26±0.03bc
$IF_{50}PM_{50}$	5.54±0.4bc	2.26±0.1ab	0.29±0.0bc	7.04±0.1c	0.3±0.05ab
$IF_{25}PM_{75}$	6.01±0.2ab	2.42±0.1ab	0.31±0.0b	8.68±0.2b	0.32±0.05ab
IF_0PM_{100}	6.21±0.3a	2.5±0.2a	0.37±0.0a	9.94±0.2a	0.38±0.06a
CV%	4.58	7.32	8.63	2.57	16.13
$LSD_{0.05}$	0.46*	0.28*	0.04**	0.30**	0.08*

Exch. = Exchangeable; IF = Inorganic fertilizers; PM = Poultry manure; NS = not significant; LSD = Least significant difference; CV= Coefficient of variance. Means within the same column followed by different letter(s) were significantly different according to DMRT (**$P<0.01$; *$P<0.05$), Values are mean ± SD.

Table 4.10b Integrated effects of IF and PM on the fertility of post harvest soils

IF and PM levels	Available S ($\mu g\ g^{-1}$)	Exch. Ca (Cmol kg^{-1})	Exch. Mg (Cmol kg^{-1})	Available Zn ($\mu g\ g^{-1}$)	Available B ($\mu g\ g^{-1}$)
IF_0PM_0	11.86±0.3d	0.25±0.0e	0.6±0.2d	1.31±0.2d	0.33±0.2a
$IF_{100}PM_0$	16.45±0.4c	2.16±0.3d	0.88±0.2cd	1.75±0.2c	0.65±0.2ab
$IF_{75}PM_{25}$	17.35±0.3c	2.53±0.1c	0.97±0.1bc	1.94±0.2bc	0.68±0.2ab
$IF_{50}PM_{50}$	18.11±1.5bc	2.75±0.1c	1.05±0.1bc	2.08±0.1b	0.74±0.2b
$IF_{25}PM_{75}$	19.35±0.6b	3.52±0.1b	1.1±0.0ab	2.19±0.0ab	0.88±0.2b
IF_0PM_{100}	22.1±1.6a	4.83±0.3a	1.31±0.1a	2.36±0.1a	0.98±0.2c
CV%	5.48	6.68	13.05	7.2	0.2584
$LSD_{0.05}$	1.71**	0.32**	0.23*	0.25**	20.55*

Exch. = Exchangeable; IF = Inorganic fertilizers; PM = Poultry manure; NS = not significant; LSD = Least significant difference; CV= Coefficient of variance. Means within the same column followed by different letter(s) were significantly different according to DMRT (**P<0.01; *P<0.05), Values are mean ± SD.

However, changes due to IF and PM was not significant because other factors such as the soil texture, pH, and the soil buffering capacity (McCauley *et al*., 2009) might had played in enabling the study soil to resist to changes brought about by IF and PM applications. The other possible mechanism through which N, P, K and S were higher in only PM treated soils could be the steady supply of N, P, K and S to plants from the fertilizer. In these conditions, plants did not depend much on soil N, P, K and S while soil N, P, K and S from other treatments were being depleted by growing plants. Poultry manure is an organic fertilizer rich in all essential plant nutrients (Gupta, 2003). PM often contains much higher nutrients than traditional organic fertilizers i.e. cowdung, sewage sludge (Alam *et al.*, 2007). Guerrero *et al.* (2001) found that organic matter addition is a suitable technique for accelerating the natural recovery process of burned soils.

4.2.4 Economic analysis

This section presents and discusses results on the gross income, net profit and cost benefit ratio (BCR) analysis of treatment combinations of IF and PM on *A.vera* cultivation to evaluate the economic feasibility of different fertilizer treatments. It gives an overview on the crop production cost components. Input costs for land preparation, seed, fertilizer, irrigation and man power required for all the operations from sowing to harvesting were calculated for cost per hectare considering the requirements per pot. For the economic analysis, the prevailing market price for inputs during planting time and outputs (*A. vera* in particular) during harvesting time was considered. The economic analysis of the present experiment is presented under the following headings-

A. Input cost

Table 4.11 Input cost for *A. vera* cultivation as influenced by IF and PM

Treatment Combinations	IF_0PM_0 (tk.)	$IF_{100}PM_0$ (tk.)	$IF_{75}PM_{25}$ (tk.)	$IF_{50}PM_{50}$ (tk.)	$IF_{25}PM_{75}$ (tk.)	IF_0PM_{100} (tk.)
Labour cost	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000
Ploughing cost	10,000	10000	10000	10000	10,000	10,000
Seedling Cost	1,60,000	1,60,000	1,60,000	1,60,000	1,60,000	1,60,000
Irrigation cost	10,000	10,000	10,000	10,000	10,000	10,000
Intercultural operations	10,000	10,000	10,000	10,000	10,000	10,000
Pesticides	15,000	15,000	15,000	15,000	15,000	15,000
Urea	0	2,400	1,800	1,200	600	0
TSP	0	1,760	1,320	880	440	0
MoP	0	2,040	1,530	1,020	510	0
Gypsum	0	210	157	105	52.0	0
Poultry manure	0	0	6250	12,500	18,750	25,000
Mustard oil cake	100	100	100	100	100	100
Total input cost	4,05,100	4,11,510	4,16,157	4,20,805	4,25,452	4,30,100

B. Overhead cost

Table 4.12 Overhead cost for *A. vera* cultivation as influenced by IF and PM

Items	IF_0PM_0 (tk.)	$IF_{100}PM_0$ (tk.)	$IF_{75}PM_{25}$ (tk.)	$IF_{50}PM_{50}$ (tk.)	$IF_{25}PM_{75}$ (tk.)	IF_0PM_{100} (tk.)
Interest on the total input cost @tk 8(%) per annum	32,408	32,920	3292	3664	3036	34,408
Interest on the value of land (Tk 100000 ha^{-1}) @ tk 8(%) per annum	2,000	2,000	2,000	2,000	2,000	2,000
Miscellaneous overhead cost (arbitrarily taken to be 5% of total input cost)	20,255	20,575	20,807	21,040	21,272	21,505
Total input cost	4,05,100	4,11,510	4,16,157	420,805	4,25,452	4,30,100
Total cost of production	4,77,763	4,85,006	4,90,257	4,95,509	5,00,761	5,06,013

C. **Gross income**

Table 4.13 Cost and profit of *A. vera* cultivation as influenced by IF and PM

Product	Yield		Value rate		Gross income (tk.)	Total cost of production (tk.)	Net profit (tk.)	Benefit cost ratio
	no. of leaf ha^{-1}	no. of seedling ha^{-1}	tk. $leaf^{-1}$	tk. $seedling^{-1}$				
IF_0PM_0	43,891	4,588	10	20	5,30,670	4,77,763	52,907	1.11
$IF_{100}PM_0$	59,447	10,145	10	20	7,97,370	4,85,006	3,12,364	1.64
$IF_{75}PM_{25}$	56,322	9,046	10	20	7,44,140	4,90,258	2,53,882	1.52
$IF_{50}PM_{50}$	52,979	7,761	10	20	6,85,010	4,95,510	1,89,500	1.38
$IF_{25}PM_{75}$	63,408	11,470	10	20	8,63,480	5,00,761	3,62,719	1.72
IF_0PM_{100}	49,560	5,912	10	20	6,13,840	5,06,013	1,07,827	1.21

Total yield (no. of leaf ha^{-1}) = total no. of plant ha^{-1}*average no. of leaves $plant^{-1}$
Gross income = Total yield (no. of leaf ha^{-1})* Value rate (Tk $leaf^{-1}$)
Net profit = Gross income - Total cost of production
Benefit Cost Ratio (BCR) = Gross income /Total cost of production

4.2.4.1 Gross income

Combination of IF and PM showed different gross income under the trial. The highest gross income (tk. 8,63,480) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest gross income (tk. 7,97,370) was obtained from $IF_{100}PM_0$. The lowest gross income (tk. 5,30,670) was calculated from the treatment combination of IF_0PM_0 (Table 4.13).

4.2.4.2 Net profit

In case of net profit, different treatment combinations showed different types of net profit. The highest net profit (tk. 3,62,719) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest net profit (tk. 8,56,449) was obtained from the treatment combination of $IF_{100}PM_0$. In contrast, the lowest net profit (tk. 52,907) was obtained from the treatment combination IF_0PM_0 (Table 4.13).

4.2.4.3 Benefit cost ratio (BCR)

The benefit cost ratio measures the efficiency of investment in *A.vera* cultivation. Average return to each taka spent on production is an important criterion for measuring profitability in growing a crop.

In the combination of different IF and PM, the highest BCR (1.72) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest BCR (1.64) was estimated from the treatment combination of $IF_{100}PM_0$. The lowest BCR (1.11) was obtained from the treatment combination of IF_0PM_0 (Table 4.13). According to Kelly and Murekezi (2000), treatments with BCR values lower than 2 are not worthy in farmers' perspectives. The farmer cannot shift from one crop cultivation to another unless benefits are sure. According to CIMMYT (1988), marginal benefits need to be 1.18 times the marginal costs to be attractive to farmers. All fertilizer treatments did not meet this requirement. The significance of economic viability of fertilizer technologies is linked to yields obtained which were highly affected by nutrient requirement of crops coupled with relatively higher total costs and marginal costs associated to the production technology. This is consistent with the result reported by Celestin (2013) in Rowanda that application of FYM and ½ DAP + ½ FYM were more profitable in maize but not in common bean and soybean. From economic point of view, it is apparent from the above results that the treatment combination of $IF_{25}PM_{75}$ and sole application of inorganic fertilizer was quit similar but considering other factors viz. growth, yield attributes, leaf biomass yield, and post-harvest soil condition, treatment combination of $IF_{25}PM_{75}$ was more profitable among the concerned treatments. Therefore, farmers would be encouraged to adopt the combined application of 75% of PM and 25% of IF for *A. vera* cultivation.

4.2.5 People's perception of medicinal and economic importance of *A.vera*

4.2.5.1 Socio-demographic characteristics of study population

A total 60 individuals were assessed to study people's perception of medicinal and economic importance of *Aloe vera.* Socio-demographic conditions of the studied individuals were also assessed. Among the individuals, 40% were female and 60% were male. The age range of the respondents was from <20 to >55. Age of majority of the respondents was in the range from 21 to 40 year *i.e.* 72.62 % of the total. Interviewed individuals were categorized into four classes on the basis of their involvement in *A. vera*. Categories included 10% farmers, 65% users and 25% hawkers. However, among the users majority of the individuals was students (41.67% of total population). Level of education of the individuals was assessed and found that about 13.1% individuals had none or primary education where 86.9% had above primary education. Among the individuals, majority (about 41.67%) had higher secondary plus education (Table 4.14).

Table 4.14 Socio-demographic characteristics of study population

Socio-demographic Variables	Frequency (n= 60)	% Respondents
Gender		
a) Male	36	60
b) Female	24	40
Age		
a) < 20 year	6	9.52
b) from 21 to 40 year	44	72.62
c) from 41 to 55 year	10	17.86
Levels of education		
a) No formal education	4	5.96
b) Primary education	5	7.14
c) Junior secondary education	7	11.90
d) Secondary education	7	10.71
e) Higher secondary education	14	22.62
f) HSC plus	25	41.67
Occupation		
a) Civil servant	2	3.57
b) Self employed	4	7.14
c) Peasant farmer	6	8.33
d) Housewife	1	1.20
e) students	47	79.76
Involvment in *Aloe vera*		
a) Farmer	6.00	10.00
b) Hawker	15.00	25.00
c) User	39.00	65
d) Dealers	-	0.00

4.2.5.1 Public perceptions regarding medicinal and economic importance of *A. vera*

This survey highlights the familiarity of respondents with *A. vera* and its use as an alternative to the conventional medicine. The prevalence of *A. vera* usage in the present study was found to be similar to the previous studies which have reported 26-79% usage for herb and dietary suppementation among college and university students (Sekhri *et al*., 2013). About 52.22% of the respondents admitted that *A. vera* is a very common herb and could be used as medicine whereas 46.26% had little knowledge (Table 4.15). About 60.77% of respondents had used *A. vera* in the past for various ailments. Only two out of sixty respondents reported side effects with the use of *A. vera* and four respondents said they did not get any effective result using *A. vera*. The side effects mentioned by the respondents were skin rash and stinging.

Table 4.15 Public perceptions regarding medicinal and economic importance of *A. vera*

Statements	Yes (%)	No (%)	Don't know (%)
Aloe vera is a very common medicinal herb	52.22	0.00	46.26
Aloe vera is very effective in curing ailments	89.13	2.40	8.67
We should advise friends, relatives or siblings to use *Aloe vera*	68.65	3.33	92.02
Aloe vera can be alternative sources of treatment of constipation and acne?	95.13	0.00	4.87
Aloe vera have some side effects too (specific)	72.48	3.33	24.19
Neonate, children, pregnant women should not take *Aloe vera*	8.45	23.91	67.64
Freshly prepared /locally prepared *Aloe vera* extracts are more effective in curing sickness	100.00	0.00	0.00
Aloe vera should be cultivated commercial throughout the country	58.43	16.79	24.78
Use of *Aloe vera* should be promoted nationally	85.00	3.00	12.00
Cultivation of *Aloe vera* is more economical than other crops	72.58	9.53	17.89

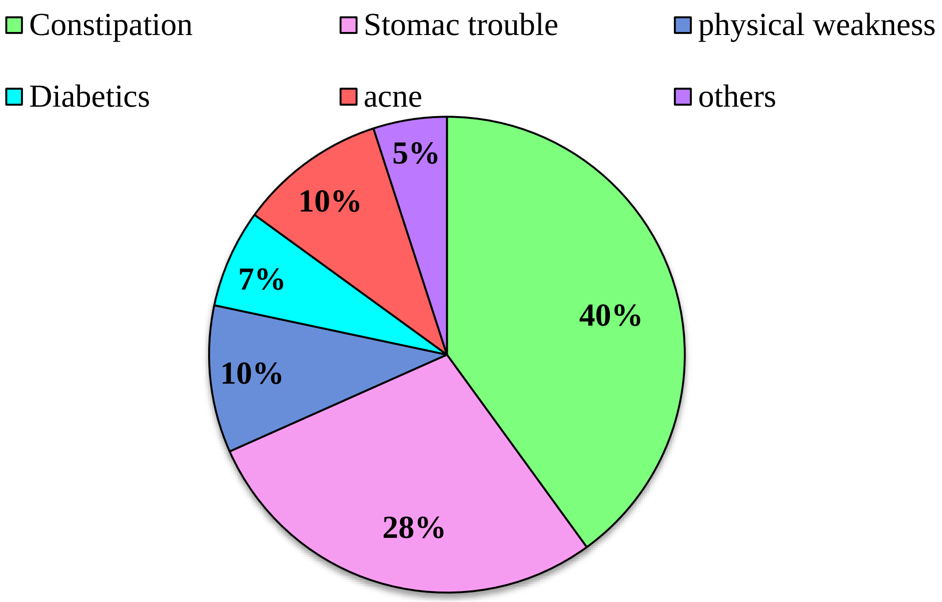


Fig. 4.14 Respondents opinion on different types of illness cured using *A. vera*

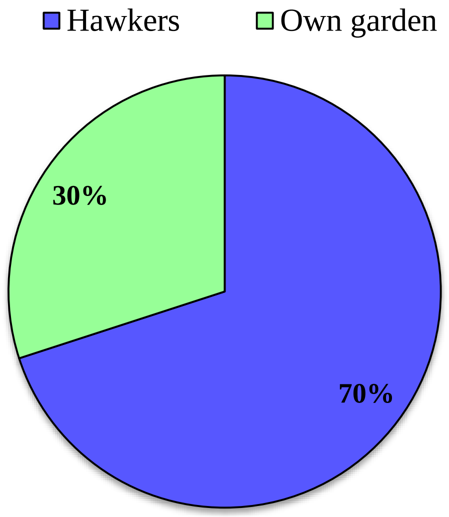


Fig. 4.15 Sources of getting *A. vera* (users)

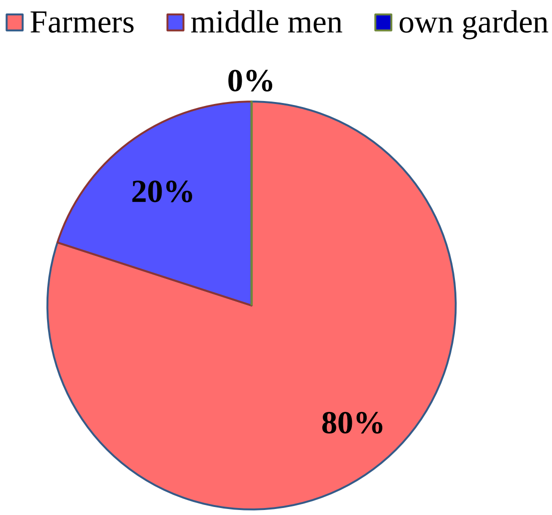


Fig. 4.16 Sources of getting *A. vera* (hawkers)

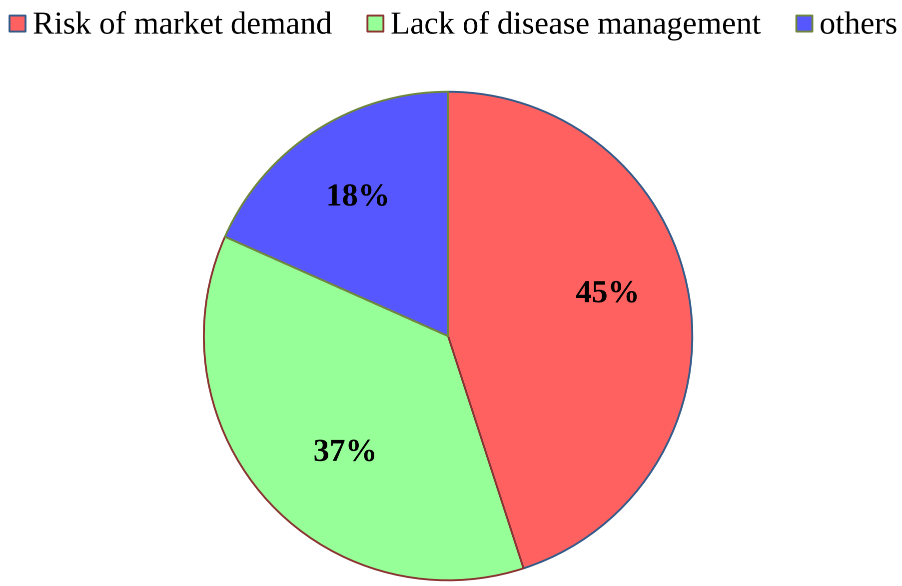


Fig. 4.17 Problems related to *A. vera* production and marketing

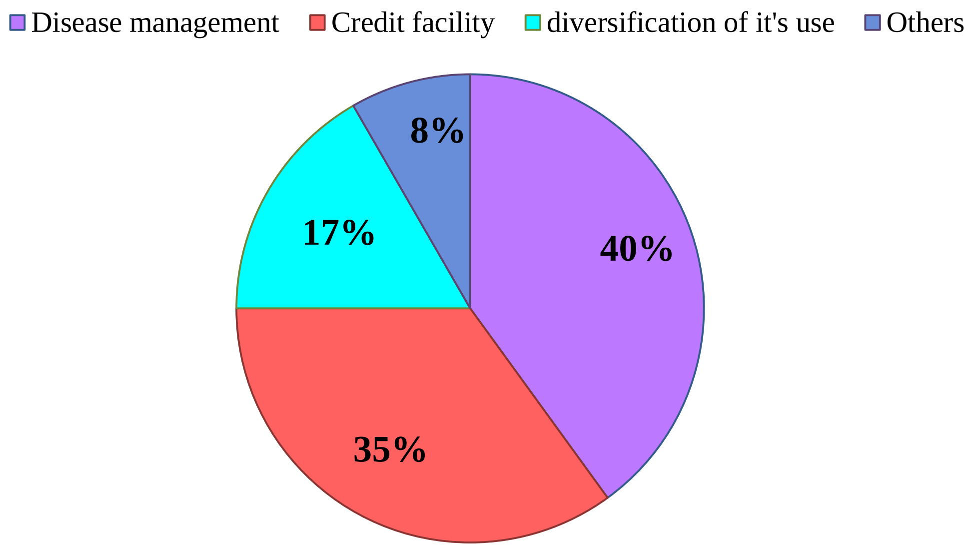


Fig. 4.18 Suggestions of the respondents to make *A. vera* more profitable

Most respondents (68.65%) agreed that they advised their friends, relatives or siblings to use *A. vera* along with the medicines prescribed by the physicians. A total of 67.64% respondents admitted their unawareness about the safety concerns associated with the use of *A. vera* by Neonate, children, pregnant women. Maximum farmers (72.58%) opined that cultivation of *A. vera* is two to three times more profitable than other crops (Table 4.15). About 100% preferred freshly prepared *A. vera* juice as it is more effective and the only form in which it is usually used in this community. Most common ailment treated with the use of this herbal remedies was found to be constipation (40%), followed in decreasing order by stomach trouble (28%), acne (10%), physical weakness (10%), diabetics (7%) and other conditions like instant body temperature reduction and memory enhancement (5%) (Fig. 4.14).

Most of the users (70%) buy *A. vera* from hawkers and only 30% had their own garden (Fig. 4.15). Hawkers mainly collect *A. vera* from the farmers (80%) and sometimes from middle men (20%) directly (Fig. 4.16). All the farmers mentioned several problems related to the production and marketing of *A. vera* such as risk of market demand (45%), lack of appropriate control measures of leaf spot disease of *A. vera* (37%), lack of land and fund, labor, irrigation, organic manure, transport and storage facilities (18%) (Fig. 4.17).

Farmers were asked to comment on the possible suggestions for solution of the problems they faced to make *A. vera* production more profitable and sustainable. They suggested several ways to minimize the problems. Development of appropriate control measures of leaf spot disease as huge amount of their production were destroyed due to leaf spot (39.10%) (Fig. 4.18). The second suggestion was easy credit facility with less interest as most of the farmers were poor (33.78%). Diversification of *A. vera* market as it was sold for only single purpose “Sherbot’’ till now, was their another suggestion (16.79%). About 85% of total respondents strongly agreed that use of *A. vera* should be promoted nationally. Other suggestions include input cost should be cheap, irrigation facilities in due time, availavility of organic and inorganic fertilizers (10.33%). Farmers believed that if the above mentioned suggestions are ensured, then commercial cultivation of *A. vera* will be increased in several folds throughout the country. Huge foreign currency can be earned by expoting this very important medicinal herb across the world due to its increasing demand.

CHAPTER 5

SUMMARY AND CONCLUSION

With the view to find out the most suitable soil(s), optimum combination of inorganic fertilizer (IF) and poultry manure (PM) for *A. vera* cultivation, integrated effects of inorganic fertilizer and PM on leaf biomass yield, nutrient uptake, pharmaceutical compounds of *A. vera* and post-harvest fertility of soil, economics of *A. vera* cultivation under different treatments and public perception regarding the medicinal and commercial importance of this plant, two experiments were conducted sequentially in the green house of BINA and open net house of the department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during 2017 – 2018. Eighteen months old *A. vera* seedlings were collected from the local farm of *Shomvogonj*, Mymensingh and planted during last week of May, 2017 and the 2^{nd} week of October, 2017 for soil screening and integrated fertilizer trial, respectively.

Eight soils from seven types namely 1. Acid 2. Calcareous 3. Non-Calcareous 4. *Charland* 5. Saline-1 6. Saline-2 7. Peat and 8. Acid sulphate were collected from different locations of seven districts of Bangladesh *viz.*, *Fulbaria* (Mymensingh), Natore *sadar* (Natore), *Agronomy field laboratory* (Mymensingh), *Melandoh* (Jamalpur), *Chokrakhali*, *Botiaghata* (Khulna), *Gamramari*, *Botiaghata* (Khulna), *Kotalipara* (Gopalganj) and *Pekua* (Cox's Bazar), respectively and used for soil screening experiment. Based on the growth, yield and yield attributes of expt. 1 (soil screening), three soils *viz.* acid, calcareous and non-calcareous were found best for *A. vera* cultivation. Since calcareous and non-calcareous soils are mostly used for growing cereals, pulses, cash crop like sugarcane, fruits etc, acid soil was used for expt. 2 considering the socio-economic conditions of the farmers. Expt.2 consisted of six levels of IF and PM combinations *viz.* 1. 0% IF + 0% PM 2. 100% IF + 0% PM 3. 75% IF + 25% PM 4. 50% IF + 50% PM 5. 25% IF + 75% PM and 6. 0% IF + 100% PM.

In soil screening experiment, well decomposed dry cow dung (CD), urea, TSP, MoP and gypsum were applied @500, 2.0, 0.9, 1.2 and 0.75 g Pot^{-1}, respectively in each pot for normal growth and development of *A. vera* seedlings. Nitrogen, P, K and S were applied as basal dose @ 150, 80, 120 and 30 kg ha^{-1} from Urea, TSP, MoP and gypsum, respectively and PM @ 5 t ha^{-1} during pot preparation of 2nd experiment. Both the experiments were laid out in completely randomized design with three replications. The data were collected at harvest of the plants.

Plant height, number of leaves, mean leaf area, fresh weight of leaves, fresh gel weight, mineral nutrients concentration and their uptake and pharmaceutical compounds were studied. Leaves were randomly selected from each pot and analyzed for nutrient concentrations and pharmaceutical constituents. Physico-chemical properties of initial and post-harvest soils were also determined.

Majority of the soils were light grey in colour except acid and peat soil which were reddish and blackish, respectively. Most of the soils were clay to clay loam in texture except non-calcareous and *charland* soil which were sandy clay loam to loam. Bulk density, particle density and field capacity varied with respect to soils and ranged from 1.23-1.45 g cc^{-1}, 2.20-2.58 g cc^{-1} and 27.07-30.20%, respectively. Chemical properties also varied across the soils. pH, EC and organic matter content ranged from 3.87-7.80, 0.25-14.04 dS m^{-1} and 0.88-16.40%, respectively. Total N, exchangeable K, available P and S concentrations ranged from 0.05-0.95%, 0.17-0.73 cmol kg^{-1} soil, 3.09-12.10 and 11.06-735.12 μg g^{-1} soil, respectively.

Soil types significantly influenced plant height, number of leaves, mean leaf area, fresh leaf weight, dry leaf weight and fresh leaf gel weight plant^{-1} at harvest. Tallest plant (44.03 cm), highest number of leaves plant^{-1} (12.67), maximum leaf area (262.70 cm^2 plant^{-1}), and highest fresh weight of leaf (1948 g plant^{-1}) were obtained from the plant grown in non-calcareous soil which was statistically identical with those plants grown in acid and calcareous soils. Maximum fresh gel weight plant^{-1} (907g) and dry leaf weight plant^{-1} (136 g) were obtained from calcareous soil which was statistically identical with those plants grown in acid soils. Highest yield increase over acid sulphate soil (734.36%) was recorded from the plant grown in calcareous soil. The lowest plant height (23.17 cm), mean leaf area (144.38 cm^2 plant^{-1}), fresh weight of leaf (233 g plant^{-1}), dry weight of leaf plant^{-1} (16.3 g) of *A. vera* from acid sulphate soil and leaf number (4.00), fresh gel weight plant^{-1} (192 g plant^{-1}) of *A. vera* was recorded from peat soil. The performance of the soils in relation to leaf biomass yield was of the following order: Calcareous ≥ Acid ≥ Non-Calcareous > *Charland* > Saline 1 > Saline 2 > Peat > Acid sulphate soils. The growth and yield parameters *viz.* plant height, number of leaves plant^{-1}, mean leaf area (cm^2), fresh leaf weight (g plant^{-1}) and fresh gel weight (g plant^{-1}) were significantly and positively correlated showing gradual increase in fresh leaf and gel weight with increasing plant height, number of leaves plant^{-1}, leaf area (cm^2) and fresh leaf weight.

The application of IF and PM in different combinations had a significant effect on the growth, yield and yield attributes of *A. vera*. Plant height, number of leaves plant^{-1}, mean leaf area and fresh weight of leaf gel plant^{-1} of *A. vera* varied with different treatments. The highest pant height (48.54 cm), leaf number (18.33), mean leaf area (334 cm^2 plant^{-1}), fresh leaf weight (4864 g plant^{-1}), fresh gel weight (2956 g plant^{-1}), dry leaf weight (420.7 g plant^{-1}) and yield increase over control (153%) of *A. vera* was obtained from the pot treated with $IF_{25}PM_{75}$ at harvest which was identical with the values obtained from the pot treated with $IF_{100}PM_0$. The lowest values of all the parameters were noticed in the control treatment (IF_0PM_0).

There was a significant effect of different levels of IF and PM on mineral nutrient concentrations and their uptake, chlorophyll, aloin, total phenolic and flavonoid concentrations of *A. vera* leaf. Concentrations of the concerned nutrients were gradually increased with the increased levels of PM except NPKS which were highest in sole application of IF. The highest concentrations of N, P, K and S had been found in *A. vera* leaves *i.e.,* 2.17, 1.20, 0.34 and 1.43% from the plants treated with 100% IF only whereas the highest concentrations of Ca (0.25%) and Mg (0.36%) were found from integrated treatment of $IF_{25}PM_{75}$ and IF_0PM_{100}, respectively. On the other hand, highest Fe (331 µg g^{-1}), Zn (80 µg g^{-1}) and Mn (223 µg g^{-1}) concentrations were obtained from 100% PM treated plants. The nutrient uptake of *A. vera* leaves was calculated using the data of the dry leaf weight and nutrient concentration. Nutrients uptakes of *A. vera* significantly varied with their addition. The highest N, P, K and S uptake were obtained from the highest addition of IF (*i.e.*, $IF_{100}PM_0$) which was identical with uptake values obtained from $IF_{25}PM_{75}$ except P and K uptake. The highest uptake of Ca, Mg, Fe, Mn and Zn were obtained from 25% IF and 75% PM. The lowest uptake of all nutrients was obtained from the plant fertilized with neither PM nor IF. Maximum protein content (15.85%) was observed in $IF_{100}PM_0$ and minimum content (10.94%) was found in control. An increased trend of chlorophyll concentration was observed with the increase of PM and CF amount. The highest chlorophyll a and chlorophyll b concentrations at harvest (0.29 and 0.116 mg g^{-1} FW, respectively) was observed in the treatment where 75% PM along with 25% IF was applied which was statistically superior to other treatments. Maximum aloin concentration (492.4 µg g^{-1}) was occurred in plants having the treatment IF_0PM_{100}. Identical amounts of leaf aloin concentration were obtained from plants treated with $IF_{25}PM_{75}$ (467.8 µg g^{-1}) and $IF_{50}PM_{50}$ (456.9 µg g^{-1}). Integrated application of IF and PM at different combination significantly affected the phenolic and flavonoid concentrations of *A. vera* gel. Highest phenolic concentration (29.08 mg g fw^{-1}) was found in $IF_{25}PM_{75}$ treated plants identically followed by the concentration (27.9 mg g fw^{-1}) obtained from 50% of IF and PM treated plants. Lowest phenolic concentration (24.54 mg g fw^{-1}) was obtained from control treatment. The highest amount of flavonoid (19.61 mg 100 g fw^{-1}) was observed in $IF_{50}PM_{50}$ treatment and the lowest amount (5.68 mg 100 g fw^{-1}) in the control.

Relationships between all the growth parameters and nutrient concentrations with leaf gel content were found positively correlated. Among the mineral nutrients, N, P, K, S, Ca, Mg and Fe concentrations were also positively correlated. Total phenolic concentration was found as strongly correlated with flavonoid. A significant correlation was also found between aloin, total phenolic and flavonoid concentrations. Ca, Mg, Fe and Mn concentrations also positively influenced the aloin, phenol and flavonoid concentrations of *A. vera* gel.

Combined application of IF and PM significantly affected the post harvest properties of acid soil. The data revealed that all parameters were significantly increased with the increased levels of PM in soil. The pH of soil increased across the treatment. Organic matter, total N, available P, exchangeable K, Ca, Mg, available S, Zn, B were significantly increased with the increased levels of PM. The highest values of all parameters were obtained from the highest levels of PM and the lowest from the control.

The highest benefit cost ratio (1.72) was obtained from the treatment combination of $IF_{25}PM_{75}$ and the second highest (1.64) benefit cost ratio was estimated from the treatment combination of $IF_{100}PM_0$. From economic point of view, it was found from the above results that the treatment combination of $IF_{25}PM_{75}$ and sole application of IF was quite similar but considering other factors like growth, yield, yield attributes and post-harvest soil fertility, treatment combination of $IF_{25}PM_{75}$ was more profitable among the concerned treatments.

A cross sectional survey on people's perception of medicinal and economic importance of *Aloe vera* in Mymensingh district was performed. Data revealed that 60.77% of respondents had used *A. vera* in the past for various ailments. Most common ailment treated with the use of this herbal remedies was found to be constipation (40%), followed in decreasing order by stomach trouble (28%), acne (10%), physical weakness (10%), diabetics (7%) and other conditions like instant body temperature reduction and memory enhancement (5%). Maximum respondents preferred freshly prepared *A. vera* juice as it is more effective and the only form in which it is usually used in this community. Maximum farmers (72.58%) opined that cultivation of *A. vera* is two to three times more profitable than other crops.

All the farmers mentioned several problems related to production and marketing of *A. vera* such as risk of market demand (46.13%), lack of appropriate control measures of leaf spot disease of *A. vera* (36.78%), lack of land and fund, labor, irrigation, organic manure, transport and storage facilities (17.09%). They suggested several ways to minimize the problems *viz*. development of appropriate control measures of leaf spot disease (39.10%), easy credit facility with less interest (33.78%), diversification of *A. vera* market (16.79%). Farmers believed that if the above mentioned suggestions were ensured, then commercial cultivation of *A. vera* will be increased in several folds throughout the country.

Conclusions

Considering the socio-economic conditions of the farmers, it might be advised to cultivate *A. vera* in acid/calcareous soils applying 75% PM (5 t ha^{-1}) along with 25% inorganic fertilizer (N, P, K and S @ 150, 120, 75 and 30 kg ha^{-1}, respectively) under the agro-climatic conditions of the experimental area.

Future research need

1. There is need to carry further studies of this investigation under field condition on macro plots followed by large scale demonstrations.

2. Identification of more pharmaceutical compounds and their biological activity to exploit high quality aloe products from *A. vera* leaves gel should be studied in Bangladesh.

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APPENDICES

Appx. 1 Fresh leaf weight of *A. vera* as influenced by different soil types of Bangladesh

Soil types	Fresh leaf weight (g $plant^{-1}$)
Acid	1768±66b
Calcareous	1896±188ab
Non-calcareous	1948±88a
Charland	1153±143c
Saline 1 (6.32 dS m^{-1})	569±28d
Saline 2 (8.14 dS m^{-1})	434±13d
Peat	262±43e
Acid Sulphate	233±11e
CV%	9.12
$LSD_{0.05}$	163.09***

CV = Coefficient of variance, LSD = Least significant difference Means within the same column followed by the same letter were not significantly different according to DMRT (***P<0.001), Values are mean ± SD (n = 3).

Appx. 2 Fresh gel weight of *A. vera* as influenced by different soil types of Bangladesh

Soil types	Fresh gel weight (g plant^{-1})
Acid	880±16.8ab
Calcareous	997±24.9a
Non-calcareous	859±27.9b
Charland	552±6.6c
Saline 1 (6.32 dS m^{-1})	427±16.6d
Saline 2 (8.14 dS m^{-1})	372±15.4e
Peat	192±19.7g
Acid Sulphate	275±13.0f
CV%	3.28
$LSD_{0.05}$	32.3

CV = Coefficient of variance, LSD = Least significant difference Means within the same column followed by the same letter were not significantly different according to DMRT (***P<0.0001), Values are mean ± SD (n = 3)

Appx. 3 Integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on the Fresh leaf weight of *A. vera*

PM and CF levels	Fresh leaf weight (g plant^{-1})
IF_0PM_0	1921±173.4d
$IF_{100\%}PM_0$	4787±452.9a
$IF_{75\%}PM_{25\%}$	3922±328.6b
$IF_{50\%}PM_{50\%}$	3677±339.1bc
$IF_{25\%}PM_{75\%}$	4864±287.5a
$IF_0PM_{100\%}$	3167±375c
CV%	9.05
$LSD_{0.05}$	599.55***

CV = Coefficient of variance, LSD = Least significant difference IF= Inorganic fertilizers; PM=Poultry manure; Means within the same column followed by the same letter were not significantly different according to DMRT (***P<0.001), Values are mean ± SD (n = 3)

Appx. 4 Integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on the fresh gel weight of *A. vera*

PM and CF levels	Fresh gel weight (g $plant^{-1}$)
IF_0PM_0	941±102.2d
$IF_{100\%}PM_0$	2854±307.07a
$IF_{75\%}PM_{25\%}$	2117±204.37b
$IF_{50\%}PM_{50\%}$	1723±352.25bc
$IF_{25\%}PM_{75\%}$	2956±218.43a
$IF_0PM_{100\%}$	1450±144.63c
CV%	12
$LSD_{0.05}$	423

CV = Coefficient of variance, LSD = Least significant difference
IF= Inorganic fertilizers; PM=Poultry manure; Means within the same column followed by the same letter were not significantly different according to DMRT (***P<0.001), Values are mean ± SD (n = 3)

Appx. 5 Integrated effects of inorganic fertilizer (IF) and poultry manure (PM) on protein content of *A. vera*

PM and CF levels	Protein content (%)
IF_0PM_0	10.94±0.11d
$IF_{100\%}PM_0$	15.85±0.14a
$IF_{75\%}PM_{25\%}$	12.53±0.0.16c
$IF_{50\%}PM_{50\%}$	13.94±0.14b
$IF_{25\%}PM_{75\%}$	15.11±0.03ab
$IF_0PM_{100\%}$	12.16±0.09cd
CV%	5.28
$LSD_{0.05}$	1.26***

CV = Coefficient of variance, LSD = Least significant difference
IF= Inorganic fertilizers; PM=Poultry manure; Means within the same column followed by the same letter were not significantly different according to DMRT (***P<0.001), Values are mean ± SD (n = 3)

Appx. 6 An interview schedule on people's perception of medicinal and economic importance of *Aloe vera*

Serial No: …………………..
Date: ……………
Name of data collector: …..
Region: ………….

A) General information:

1. Name of the respondent: …………………………………………………………
2. Father /Husband name: ……………………………………………….

Mobile No: ………………….

B) Socio-demographic characteristics

1. Gender:

a) Male
b) Female

2. Age: .... years

3. Occupation:

a) Civil servant
b) Self employed
c) Peasant farmer
d) Housewife
e) Student

4. Years of schooling: .... years

5. Involvement in *Aloe vera*

a) Farmer
b) Hawker
c) User
d) Dealers

D. Some common questions about *A. vera*

1. Do you know about *Aloe vera*? ....
2. In which froms *Aloe vera* is usually used in this community? ……………….
3. What are the illnesses that can be cured by *Aloe vera*?.....................................

4. Do you have *Aloe vera* in your garden/plantation (users)?...................................
5. If no where do you get *Aloe vera* from if you need it? ....
6. Is there anything you would like to let me know about *Aloe vera* that we have left out?
   ……………………………………………………………………..

7. How many years are you engaged in Aloe vera cultivation/business? ....

8. From where you buy *Aloe vera* usually? (if the respondent is a hawker)
   ………………………………………………………………………………………

9. What are the marketing problems related to *Aloe vera*? ....
10. What are your expectations/ needs in your profession to make *Aloe vera* sustainable/ profitable?
    ………………………………………………………………………………………

C. Questions on public perceptions:

Statements	Yes	No	Don't know
Aloe vera is a very common medicinal herb			
Aloe vera is very effective in curing ailments (specific)			
We should advise friends, relatives or siblings to use *Aloe vera*			
Aloe vera can be alternative sources of treatment of constipation and acne?			
Aloe vera failed to cure any illness			
Aloe vera have some side effects too (specific)			
Neonate, children, pregnant women should not take *Aloe vera*			
Freshly prepared /locally prepared *Aloe vera* extracts are more effective in curing sickness			
Aloe vera should be cultivated commercial throughout the country			
Use of *Aloe vera* should be promoted nationally			
Cultivation of *Aloe vera* is more economical than other crops			

Appx. 7 Monthly average temperature, humidity, rainfall and sunshine data during the experimental period from 2017-2018.

Month	2017-2018			
	Mean temp. (^{O}C)	**Mean hum. (%)**	**Total rain (mm)**	**Total sun-shine (hrs)**
May/17	29	82	589	124
June/17	29	85	495	101
July/17	29	87	368	89
August/17	30	87	437	97
September/17	29	85	434	101
October/17	28	86	19	197
November/17	24	73	25	197
December/17	21	85	34	155
January/18	20	84	1	133
February/18	21	74	12	191
March/18	30	74	33	217
April/18	28	78	80	233

Temp. = Temperature, Hum. = Humidity, Rain = Rainfall, Sun-shine = Sunshine.

Source: Weather record, Department of irrigation and water management, Bangladesh Agricultural University.

Appx. 8 Map showing the locations of soil sampling sites of Bangladesh

Appx. 9 Photographs of collection and preparation of soils and pots for *A. vera* cultivation

Collected soils

Preparation of soils

Sieving of soils and pot preparation

Preservation of soils for chemical analyses

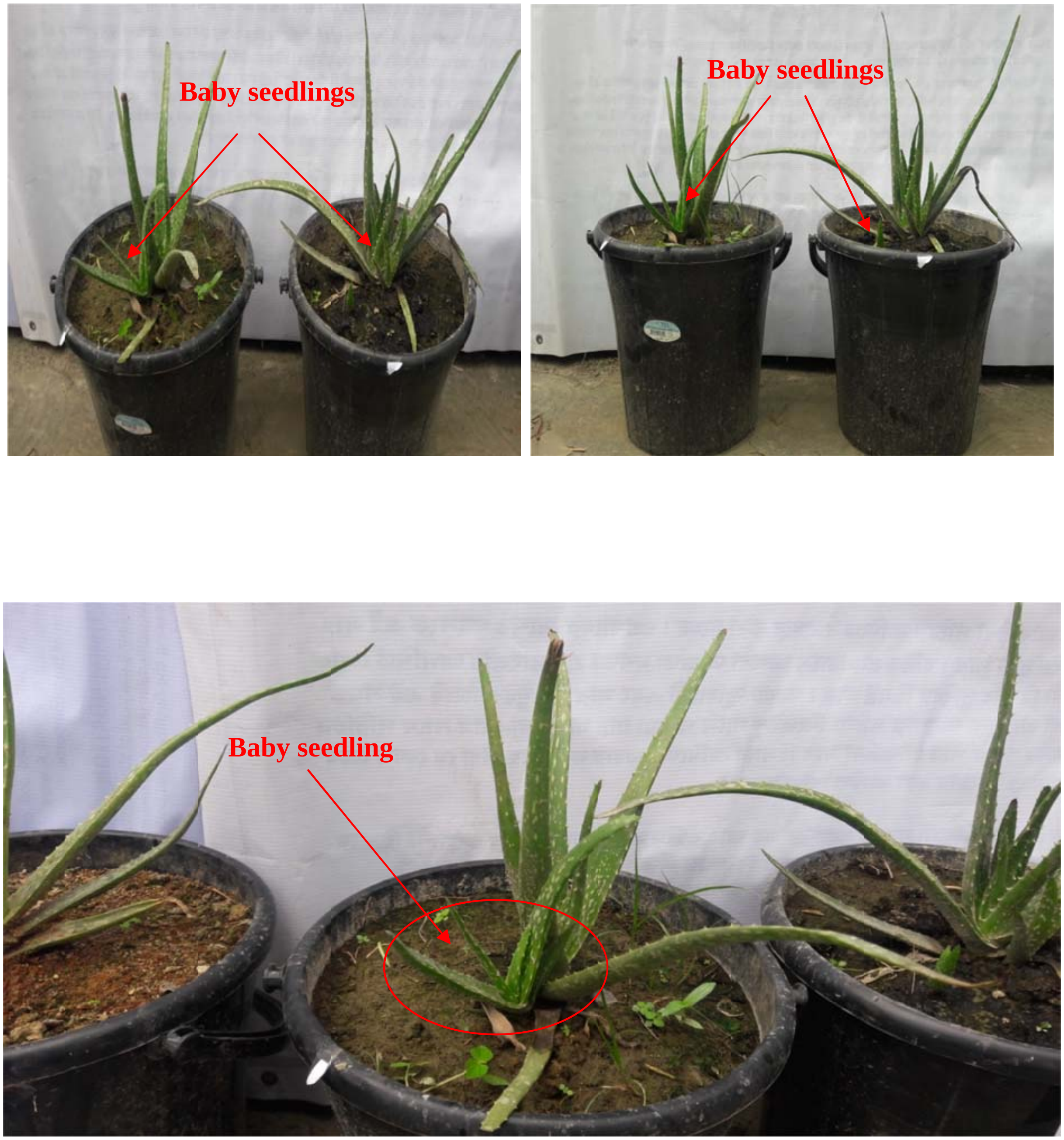
Planting *A. vera* seedling

Growing of *A.vera* seedling

Appx. 10 Photographs of *A. vera* plants in different types of soils (growth stage)

Different growth stages of *A. vera* as influenced by different types of soils

Different growth stages of *A. vera* as influenced by different combinations of IF and PM



Mother *A. vera* plant with baby seedlings

Appx. 11 Photographs of *A. vera* leaves at harvest as influenced by soil types and integrated IF and PM

A. vera leaves at harvest as influenced by different soil types

A. vera leaves at harvest as influenced by different combinations of IF and PM

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Author	TANZIN CHOWDHURY
Department	Agricultural Chemistry
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